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SENSORY TESTING OF CIGARETTE SMOKE

PANEL SELECTION, TRAINING AND USE

BY

FAWKY MOHAMED ABDALLAH

UNDER THE DIRECTION OF JOSEPH A. MEYBOEM AND
ROBERT J. MONROE

NORTH CAROLINA STATE UNIVERSITY, RALEIGH

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Sensory testing of cigarette smoke. Panel selection, training and use. Diss. Abstr. Int. B. 35(10):4745, Apr. 1975.

Ninety-three volunteers of different ages, smoking habits, and of either sex were considered as candidates for panel training and selection. Primary taste tests were employed during training to familiarize the potential panelists with the four taste qualities, sweet, salt, sour and bitter. There was no significant difference in taste sensitivity between smokers and non-smokers or between cigarette smokers and non-smokers. Selection of a panelist was based on his ability to detect three types of differences similar to those that might be encountered during the actual testing of experimental cigarettes. Selection techniques were designed not only to qualify subjects as panelists but also to train them on how to detect difference becomes smaller. Panel training continued by measuring the panelist's response (correct identification of the odd cigarette) to changes in smoke flavor due to added sugar and to added nicotine malate, each at four different concentrations. The relationship between panel response and the added concentrations of either additive was linear when response was plotted against log-concentration, suggesting conformance with the Weber-Fechner Law. A method was developed to determine the panelist's just-noticeable-difference significant at the 5% level ($JND._{.05}$) for added sugar and for nicotine malate. The $JND._{.05}$ was 11 mg sugar per gram of tobacco and 6.7 mg nicotine malate (3.65 mg nicotine) per gram of tobacco, already containing 15.8% sugar and 2.14% nicotine. With proper training the number of performing panelists can be reduced. A panel of 15 individuals performed as well as did a panel of 21. A 15-member panel was then used to elucidate the qualitative diff-differences (two identical cigarettes and one different or odd) was employed. The subjects were asked to follow the order of presentation and to use a suggested smoking technique while taking the tests. All smoking tests were conducted under controlled conditions (in the booths) and cigarette marking was used as a physical method to control the amount of stimulus (smoke). Of the 36 subjects who completed the required smoking tests (15 triangles), 30 had a discriminating ability beyond the chance probability and, hence, were qualified as panelists. Correlation studies showed that cigarette smokers were more likely to have discriminating ability, to detect differences between the test cigarettes, than pipe and cigar smokers than non-smokers. In triangle smoking tests, the subjects responded correctly more often when the odd is not in the middle, and the effect of the position of the odd becomes more prominent as the erence in smoke flavor of experimental cigarettes to which equivalent supra-threshold amounts of "free" nicotine and "bound" nicotine (nicotine malate) had been added. The panel response in four triangles indicated a significant difference in smoke flavor attributed to the two forms of nicotine. Even with only two triangles, the panel was able to detect the difference. When the panelists were permitted to take the test cigarettes ad libitum instead of in-booth, the differences was not detected. The panel's high performance was due not only to the panelists themselves (training) or the type of difference to be detected by also to the three-fold criterion of sensory testing; test materials, test procedure and test conditions.

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ABSTRACT

ABDALLAH, FAWKY MOHAMED. Sensory Testing of Cigarette Smoke. Panel Selection, Training, and Use. (Under the direction of JOSEPH A. WEYBREW and ROBERT J. MONROE.)

Ninety-three volunteers of different ages, smoking habits, and of either sex were considered as candidates for panel training and selection.

Primary taste tests were employed during training to familiarize the potential panelists with the four taste qualities, sweet, salt, sour, and bitter. There was no significant difference in taste sensitivity between smokers and non-smokers or between cigarette smokers and non-smokers.

Selection of a panelist was based on his ability to detect three types of differences similar to those that might be encountered during the actual testing of experimental cigarettes. Selection techniques were designed not only to qualify subjects as panelists but also to train them on how to detect differences. In all smoking tests, the triangle method for detecting differences (two identical cigarettes and one different or odd) was employed. The subjects were asked to follow the order of presentation and to use a suggested smoking technique while taking the tests. All smoking tests were conducted under controlled conditions (in the booths) and cigarette marking was used as a physical method to control the amount of stimulus (smoke).

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Of the 36 subjects who completed the required smoking tests (15 triangles), 30 had discriminating ability beyond the chance probability and, hence, were qualified as panelists. Correlation studies showed that cigarette smokers were more likely to have discriminating ability, to detect differences between the test cigarettes, than pipe and cigar smokers than non-smokers.

In triangle smoking tests, the subjects responded correctly more often when the odd is not in the middle, and the effect of the position of the odd becomes more prominent as the difference becomes smaller.

Panel training continued by measuring the panelist's response (correct identification of the odd cigarette) to changes in smoke flavor due to added sugar and to added nicotine malate, each at four different concentrations. The relationship between panel response and the added concentrations of either additive was linear when response was plotted against log-concentration, suggesting conformance with the Weber-Fechner Law. A method was developed to determine the panelist's just-noticeable-difference significant at the 5% level ($JND_{.05}$) for added sugar and for nicotine malate. The $JND_{.05}$ was 11 mg sugar per gram of tobacco and 6.7 mg nicotine malate (3.65 mg nicotine) per gram of tobacco, already containing 15.8% sugar and 2.14% nicotine. With proper training the number of performing panelists can be reduced. A panel of 15 individuals performed as well as did a panel of 21.

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A 15-member panel was then used to elucidate the qualitative difference in smoke flavor of experimental cigarettes to which equivalent supra-threshold amounts of "free" nicotine and "bound" nicotine (nicotine malate) had been added. The panel response in four triangles indicated a significant difference in smoke flavor attributed to the two forms of nicotine. Even with only two triangles, the panel was able to detect the difference. When the panelists were permitted to take the test cigarettes ad libitum instead of in-booth, the difference was not detected. The panel's high performance was due not only to the panelists themselves (training) or the type of difference to be detected but also to the three-fold criterion of sensory testing; test materials, test procedure and test conditions.

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SENSORY TESTING OF CIGARETTE SMOKE.

PANEL SELECTION, TRAINING, AND USE

by

FAWKY MOHAMED ABDALLAH

A thesis submitted to the Graduate Faculty of
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in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

DEPARTMENT OF CROP SCIENCE

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BIOGRAPHY

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Fawky M. Abdallah was born , in Cairo, Egypt. He received his Bachelor of Science degree with a major in agriculture from Cairo University in 1959.

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In 1969 he published a series of articles on tobacco quality, which in 1970 were condensed into a book entitled "Can Tobacco Quality Be Measured?"

In April 1970 he resigned from Eastern Company to pursue a graduate program leading to the Ph.D. degree in the Department of Crop Science, North Carolina State University, Raleigh, North Carolina.

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2028559572

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TABLE OF CONTENTS

	Page
LIST OF TABLES	viii
LIST OF FIGURES	xii
1. INTRODUCTION	1
2 REVIEW OF LITERATURE	3
2.1 Physical and Chemical Properties of Smoke	3
2.2 Sensory Properties of Smoke	6
2.2.1 Taste	7
2.2.2 Odor	9
2.2.3 Feel or Touch	13
2.2.4 Smoke Flavor	14
2.3 Sensory Testing of Smoke Flavor	19
3 EXPERIMENTAL ARRANGEMENT	25
3.1 The Size of Panel	25
3.2 Selection of Candidates	26
3.3 Testing Conditions	28
3.4 Testing Methods	32
4 PRIMARY TASTE TESTING	36
4.1 Introduction	36
4.2 Materials and Methods	36
4.2.1 Threshold Determination	36
4.2.1.1 Sample Preparation	37
4.2.1.2 Sample Serving	37
4.2.1.3 Test Procedure	39
4.2.2 Measurement of Acuity Value	41
4.2.2.1 Sample Preparation and Serving	41
4.2.2.2 Test Procedure	42
4.3 Results and Discussion	42
4.3.1 Threshold Values	42
4.3.2 Acuity Values	45
4.3.3 Smoking and Taste Sensitivity	48
5 PANEL SELECTION AND TRAINING	55

2028559573

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

TABLE OF CONTENTS (continued)

	Page
5.1 Introduction	55
5.2 Materials and Methods	57
5.2.1 Design of the Test Cigarettes	57
5.2.2 Cigarette Making and Marking	57
5.2.3 Cigarette Handling, Coding and Serving	60
5.2.4 Smoking Technique	62
5.2.5 Design of Smoking Comparisons	65
5.3 Results and Discussion	68
5.3.1 Panel Selection	68
5.3.2 Statistical Analysis of Panel Results	71
5.3.3 Effect of the "Odd" Position	84
6 "CALIBRATION" OF THE PANEL PERFORMANCE	92
6.1 Introduction	92
6.2 Materials and Methods	93
6.2.1 Design of the Test Cigarettes	93
6.2.2 Design of the Smoking Comparisons	96
6.3 Results and Discussion	98
6.3.1 Panel Threshold (JND) for Sugar	98
6.3.2 Panel Threshold (JND) for Nicotine Malate	110
6.3.3 Checking the Panel Performance	116
6.3.4 Effect of the Odd Position	120
7 USE OF PANEL AS A RESEARCH TOOL	123
7.1 Introduction	123
7.2 Materials and Methods	124
7.2.1 The Test Cigarettes	124
7.2.2 The Smoking Comparisons	125
7.3 Results and Discussion	126
7.3.1 Free versus Bound Nicotine	126
7.3.2 Two versus Four Triangles	129
7.3.3 In-booth versus Take-out	132
8 SUMMARY	136
9 CONCLUDING REMARKS	140

2028559574

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TABLE OF CONTENTS (continued)

Page

10 LIST OF REFERENCES 142

11 APPENDIX 150

2028559575

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

LIST OF TABLES

Page

Text

4.1 Subjects' mean and range of threshold values in mM/l for the four primary tastes 44

4.2 Subjects' mean and range of acuity (sensitivity) values as Kendall's τ for the four primary tastes 47

4.3 Paired-comparison between means of primary taste sensitivities of smokers and non-smokers . . . 49

4.4 Paired-comparison between means of primary taste sensitivities of selected cigarette smokers versus non-smokers 53

5.1 Principle sources of variability in sensory testings (subjective responses) 56

5.2 Experimental cigarettes for panel selection and training 58

5.3 Subjects' mean and range of total scores in all smoking tests for panel selection and training (15 triangles) 70

5.4 Subjects' mean scores in each of the smoking comparisons for panel selection and training . . 72

5.5 Classification of panelists according to their smoking habits 74

5.6 Stratification of the subjects' smoking intensity values {SMKINT = (years of smoking x cigarettes smoked/day)/100} 75

5.7 Mean smoking scores by all subjects and selected panelists ranked according to SMKINT-C 77

5.8 Regression of mean scores of all subjects and panelists with relation to their smoking intensity, SMKINT-C 79

5.9 Mean smoking scores for different groups among all subjects and selected panelists 83

5.10 Correlation and Chi-square studies between the subjects' smoking scores in the three smoking comparisons 83

2028559576

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

LIST OF TABLES (continued)

		Page
5.11	Subjects' response (score) as affected by the position of the odd in triangle smoking tests for panel selection and training	86
5.12	Effect of "odd" position on the proportion of subjects' score in triangle smoking tests for panel selection and training	88
5.13	Combined effect of "odd" position (middle versus other) on subjects' response in triangle smoking tests for panel selection and training	90
6.1	Experimental cigarettes used in triangle smoking tests for the determination of panel threshold (JND) for added sugar or nicotine malate	94
6.2	Panelists' proportions of correct identification of the odd in triangle smoking tests for sugar threshold (JND) determination	99
6.3	Analysis of variance -- regression of panelists' proportions of correct identification of the odd on levels of added sugar (using 21 panelists)	100
6.4	Analysis of variance -- regression of panelists' proportions of correct identifications of the odd on ln (sugar) levels (using 21 panelists)	104
6.5	Panelists' proportions of correct identifications of the odd in triangle smoking tests for nicotine malate threshold (JND) determination	111
6.6	Analysis of variance -- regression of panelists' proportions of correct identifications of the odd on ln (nicotine malate) levels (using 15 panelists)	111
6.7	Panelists' proportions of correct identification of the odd in triangle smoking tests for sugar JND. Results of the 15 panelists who completed the nicotine malate tests	117
6.8	Analysis of variance -- regression of panelists' proportions on ln (added) sugar for the 15 panelists who completed the nicotine malate tests	118

2028559577

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

LIST OF TABLES (continued)

Page

6.9 The effect of position of the odd cigarette on the panelists' response in triangle smoking tests for JND determination 122

7.1 Panelists' responses in four triangle smoking tests for nicotine versus nicotine-malate cigarettes 127

7.2 Panelists' responses in the first two triangle smoking tests for nicotine versus nicotine malate cigarettes 130

Appendix

1. Concentrations of solutions used in primary taste testings 151

2. Subject's thresholds (mM/l) and acuity values (Kendall's τ) for the four primary tastes . . . 152

3. Correlation between the subjects' acuity values to the four primary tastes 154

4. Chi-square test of the subjects' acuity values to the four primary tastes 154

5. Comparison between primary taste sensitivity of smokers versus non-smokers 155

6. Comparisons between primary taste sensitivity of selected cigarette smokers versus non-smokers . . 157

7. Statistical information covering the 36 subjects who completed all required smoking tests for panel selection and training 158

8. Analysis of variance, regression of SMKINT-C on average score in triangle smoking tests for panel selection and training 159

9. Subjects' scores in smoking comparisons for panel selection and training 160

10. The subjects' identification of the odd cigarette in smoking tests (3 comparisons x 5 triangles) for panel selection and training 161

2028559578

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

LIST OF TABLES (continued)

Page

11. Panelists' scores as affected by the position of the odd cigarette in triangle smoking tests for panel selection and training 162

12. Effect of odd position on the proportion of panelists' score in triangle smoking tests for panel selection and training 163

13. Combined effect of odd position (middle versus others) on panelists' response in triangle smoking tests for panel selection and training . 163

2028559579

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

LIST OF FIGURES

Page

Text

3.1 Smoke Evaluation Laboratory showing booths in the open configuration 31

4.1 Serving of taste solutions for primary taste testing 38

4.2 Presentation of primary taste solutions for determination of taste threshold by the method of limits 40

4.3 Presentation of primary taste solutions for the determination of the acuity (sensitivity) values by the ranking method 43

5.1 A convenience rack for proper storage and handling of cigarettes prior to coding and serving to the panelists 61

5.2 Booth prepared for a triangle smoking test. The test cigarettes are arranged on the ashtray; the butane lighter, the instruction sheet and the response card are clearly visible 63

5.3 Three coded cigarettes presented on the ashtray (in a specific order) for a triangle smoking test. The two marks on each cigarette are used to control the amount of stimulus (smoke) . . 64

5.4 A panelist taking a triangle smoking test in the booth to minimize the influence of extraneous (non-stimulus) variables on the subject's response 66

5.5 The relationship between mean scores of 36 subjects and their smoking intensities, SMKINT-C 80

5.6 The relationship between mean scores of the 30 selected panelists and their smoking intensities, SMKINT-C 81

6.1 The relationship between panel response (mean proportions of 21 panelists) and added amounts of sugar (mg/g) 101

6.2 The relationship between panel response (mean proportions of 21 panelists) and added sugar (mg/g on a logarithmic scale) 106

2028559580

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

LIST OF FIGURES (continued)

		Page
6.3	The relationship between panel response (mean proportions of 15 panelists) and added nicotine malate (mg/g on a logarithmic scale)	113
6.4	The relationship between panel response (mean proportions of 15 panelists) and added sugar (mg/g on a logarithmic scale)	119
7.1	Panelist discussing the test results and procedures with the sensory analyst. Booths are closed	133
7.2	The theory of the distance model as applied to triangle smoking tests is explained to the panelists to improve their performance . . .	135

Appendix

1.	Memorandum to the tobacco staff, North Carolina State University, explaining the objectives of the panel program and asking for volunteers .	165
2.	Informing the people of the importance of the research program and of the contribution it will add, would presumably increase each individual's motivation and elicit his interest in participating in the panel project.	167
3.	Some pertinent statistics about each volunteer are supplied by a questionnaire	169
4.	A letter addressed to each candidate expressing appreciation for his willingness to cooperate and asking him to indicate the time(s) he might be available	171
5.	Layout of the Smoke Evaluation Laboratory . . .	172
6.	Smoke Evaluation Laboratory; elevation of the six-partitioned booths and the main duct (booth doors are opened and stools in) . . .	173
7.	Smoke Evaluation Laboratory; sectional plan A-A of Appendix Figure 6	174
8.	Perspective view of a smoking booth	175

2028559561

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

LIST OF FIGURES (continued)

Page

9. Instruction sheet for threshold determination by the method of limits 177

10. Response card for threshold determination by the method of limits 178

11. Instruction sheet for the determination of acuity (sensitivity) value by the ranking method 180

12. Response card for the determination of acuity (sensitivity) value by the ranking method . . . 181

13. Smoking technique for use in detecting differences by the triangle method 183

14. Response card for triangle smoking tests 185

15. Reassigning smoking intensity value for pipe and cigar smokers (among all 36 subjects) by employing their average score 186

16. Reassigning smoking intensity value to pipe and cigar smokers (among the 30 selected panelists) by employing their average score 187

17. A letter informing the prospective panelists of their results in the primary taste tests during panel selection and training 189

18. To increase their interest and motivation, panelists were adequately informed of their selection as panel members and of the important role of the panel in the evaluation of smoke flavor 191

2028559582

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1. INTRODUCTION

The flavor excellence of U. S. flue-cured tobacco is readily acknowledged. Despite its high quality, the high and continually rising price is causing both domestic and foreign customers to look for cheaper supplies of "filler" tobaccos (3). Some are even exploring non-tobacco substitutes. Thus to remain competitive, tobacco scientists and growers must avail themselves of every opportunity for reducing the costs of production.

In addition, the rapidly shrinking labor force is already dictating drastic changes in the culture of tobacco. Mechanical harvesting and concomitant modification of curing structures and methods are imminent. Researches aiming at accommodating mechanization are underway. More uniformly-ripening varieties with more nearly perpendicular leaf angles are being sought (85). Cultural modifications including staggered plantings, lower topping, fewer but heavier harvestings, even including once-over harvest, are being studied (84). The management of ripening is being attempted through the application of chemical retardants and/or accelerators. It is inconceivable that some of these treatments would not alter to some degree the flavor of the cured tobacco. To date, however, chemical analyses of the cured leaf and even those of the smoke cannot be correlated specifically with overall smoke flavor. Therefore, since "the proof of the pudding" still resides on the palate of

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the consumer, the ultimate assessment of smoke flavor can be determined only through the smoking of cigarettes. Thus a smoke evaluation panel is an important and necessary adjunct to any aggressive and progressive tobacco research program.

The present project was undertaken to select, from among an unrestricted group of volunteers, a panel of smokers; to train these panelists in the rudiments of taste testing; to establish experimentally their reliabilities for detecting differences; and finally, to utilize this panel for the evaluation of the smoke flavor of experimental cigarettes.

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2. REVIEW OF LITERATURE

2.1 Physical and Chemical Properties of Smoke

The cigarette is a unique product of human consumption. While all other products are consumed in the solid or liquid form in which they are presented, cigarettes are consumed in the form of smoke. During smoking the tobacco fuel is transformed from the solid state into the complex aerosol that is smoke. It is not surprising therefore that the quality of smoke reflects to one degree or another the chemistry of the tobacco. However, other factors, e.g. burning conditions and geometry of the cigarette and filler, also influence the composition of the smoke. At temperatures above the ignition point, reactions of pyrolysis are initiated (in a gradient zone preceding the burning cone) and drastic changes occur in the constituents of tobacco. The maximum temperature in the cigarette cone is 880°C (86).

Since smoke is the ultimate product of consumption, numerous investigations have been undertaken to determine its physical properties and chemical composition (32, 71, 77). Smoking machines that simulate human smoking are utilized to generate smoke for chemical and physical analyses. In cigarettes a sharp thermal gradient is found in a narrow zone ahead of the burning cone and this gradient varies with the length of the remaining butt. Volatilization, distillation, sublimation, pyrolysis, chemical interactions and possibly mechanical cellular eruption occur within this

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region, whereas oxygen plays a minor role (78). The smoke is hence, formed and its mainstream proceeds rapidly down the cigarette during the "draw" and is further diluted with air which permeates the cigarette paper.

The smoke composition is also influenced by the geometry of the cigarette (manufacturing). For example, cigarette length, width (circumference), firmness, draw-resistance (or pressure-drop), type of cigarette paper and type of cigarette filter greatly affect the condition of the combustion and/or the composition of the mainstream smoke. Of equal importance is the size of the tobacco-cut (e.g. 32 cuts per inch versus 40); the finer the cut the greater the exposure to the burning.

Partial deposition of smoke occurs as the smoke travels along the cigarette and the condensed material is again subjected to heat and revolatilized as the cone moves down the cigarette. The compositional nature of the smoke is thus determined by the thermal gradient in the narrow region ahead of the cone and changes from puff to puff (32, 71).

Cigarette smoke is an aerosol having a discontinuous phase commonly called total particulate matter (TPM), which is about 8% of the total weight, and a continuous phase (gaseous) composed of vapors (19%), excess nitrogen (15%) and air (58%). Fresh mainstream smoke contains about 1×10^9 to 5×10^9 particles per ml. The particle size ranges from .1 to 1μ. The physical characteristics of the smoke changes rapidly upon emission from the cigarette tip

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with particles rapidly agglomerating (32). Fresh smoke is a dynamic system and changes rapidly upon aging or when dissolved in solvents for chemical analysis (21). That is, the substantial properties of smoke aerosol changes when set in solution as the reaction field changes from particles distributed in the aerosol space to merely concentration of molecules in the volume unity of solvent.

By 1972, a little more than 1500 chemical compounds had been identified in tobacco leaf and/or cigarette smoke (71). One of the current major problems in research on cigarette smoke evaluation is the determination of the components actually present in the fresh mainstream smoke and the correlation of such with the leaf chemistry and the sensory properties of the smoke. The subject of sensory properties of cigarette smoke investigates the possible interactions of some smoke components (singly and in combination) with the sensory organs of the smoker. The major part of the sensory properties of smoke is believed to be due to some components in the TPM which include 100 polynuclear-aromatic hydrocarbons (PAH), about 35 sterols and 55 aldehydes and ketones, over 40 acids (especially volatile acids), about 80 phenols and polyphenols, almost 125 alkaloids and volatile bases, about 50 carbohydrates (including hexoses and pentoses) and 40 amino acids and proteins (2). Hence, there exist within the TPM (8% of smoke aerosol by weight) over 500 component-substances, each contributing in one way or another to the smoke chemistry

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and to the overall sensory properties of cigarette smoke -- commonly called smoke flavor.

2.2 Sensory[1] Properties of Smoke

Of the five known senses (taste, smell, touch, hearing and vision) only three are believed to be directly involved during smoking (taste, smell and feel or touch) with the other two indirectly involved in establishing the habit. Various studies (22) on smoking suggested the following three propositions: (a) one smokes primarily for the physiological response to inhaled smoke, (b) the primary constituent in cigarette smoke which produces the sought-after physiological response is nicotine, and (c) the sought-after physiological responses result in increased psychological efficiency. In a recent report (22) it was stated that the habit-forming process is due to both the physiological effect of nicotine and other related alkaloids as well as the psychological effect of the inhaled smoke. Thus both effects are bound together by a postulated sequence of events:

$$\text{Smoke Inhaled} \rightarrow \text{Nicotine Absorbed} \rightarrow \text{Improved Psychological Efficiency} \rightarrow \text{Physiological Response}$$

It has also been established that the habit is developed after a certain period of time during which the subject smokes the

[1]The term "sensory" is now employed more often than "organoleptic", as some sensory systems used in flavor evaluation of products do not have specific organs and thus lack certain sensations, e.g. feeling or tactile and thermal sensations.

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product and finds it agreeing well with his sensory appreciation. The habit is developed when a certain level of nicotine intake is established in the subject's system (22). Simply, the subject has to "like" the product (sensorily) and smoke it for a period of time before the smoking habit is ever developed.

The type and magnitude of the over-all sensory properties of smoke are related to the taste impressions perceived when the smoke is taken into the mouth; the odor factors registered as the smoke is exhaled through the nasal cavity, as well as the feeling sensations (tactile) and often after-taste (2). All three sensations (taste, odor and feel) are noted during the smoking (inhaling-exhaling) without having time to ponder on any particular sensation. It is impossible to prolong these sensations and analyze them during the puff. For research on smoke flavor, these sensations must be separated and analyzed systematically; however, it is the close "marriage" among these sensations that gives rise to the smoking enjoyment in the form of a desirable blend of sensations or flavor bouquet.

2.2.1 Taste

The commonly accepted theory of taste is that there are four primary or basic taste qualities: sweet, salt, sour and bitter. Each of the approximately 10,000 taste buds on the tongue and pharynx has 15-20 taste cells arranged in bud-like form from its tip. The individual cells vary in

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their responses to the four primary taste stimuli, that is, some cells may respond to sugar and salt, whereas others in the same taste bud may respond to salt and acids. Much has been learned during the last several years about the nature of the mechanism of taste perception (7, 8, 10, 56, 67). The initial step appears to be a chemical one: stimulation by a taste substance (in solution) depolarizes the taste cell and a weak bond is formed between the ion or molecule of the taste substance and the molecular structure of the taste cell surface. This depolarization in turn excites the nerve fibers and gives a rise to a nerve impulse to the brain where a taste is registered. The differences in configuration of the taste cell surfaces account for the selective absorption of a particular taste substance. There is no specific receptor cell for each of the four taste qualities. As a taste solution increases in concentration, there is a corresponding increase in the number of impulses fixed by the nerve fibers. Other taste substances will also produce impulses in the same fiber but at different thresholds.

Sweet taste is exhibited by organic molecules and by ions. Sweetness is exhibited by compounds such as polysaccharides and alpha amino acids, though solutions of alkalies in proper dilutions give a sweet taste. Saltiness is exhibited by sodium chloride and is based on ionic effect, which is also true with sourness but not with sweetness and bitterness. Sourness is associated with hydrogen ion concentration as well as the total amount of acid.

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Differences in sourness of the acids can be attributed to variations in the pH of the saliva. Bitterness is typically caused by alkaloids such as quinine, morphine, strychnine and caffeine, however, it may be also caused by ions of magnesium, ammonium and calcium. Once the sensation of bitterness has been detected it can last for a considerably longer period of time (duration) than in the case of sour, salt or sweet sensation.

In addition to the four primary tastes there is also another characteristic, viz. tastelessness. For man, distilled water is tasteless liquid; it does not excite his taste buds. An individual needs training to build up a reaction that enables him to think of distilled water as tasteless (5).

Because any product taken by mouth usually includes two or more of the primary tastes, the specific action these tastes have on each other has been reported (57, 58). The effect of one taste on another is well known and the "toning-down" of sensations when two tastes are presented simultaneously is called compensation. Taste is also influenced by temperature. Warm and cold stimuli act similarly on the four primary taste stimuli and the six different sensations on the tongue can be divided into two groups: bitter, sweet, warm; and sour, salt, cold (11).

2.2.2 Odor

Odor is one of the sensations perceived as a part of the flavor which includes taste, odor and feel or touch.

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At this stage it is important to define some of the terms often used by sensory analysts. Olfaction is the sense of smell whereas gustation is the sense of taste. In the exact meaning, odor refers to the stimulus or the sensation resulting from stimulation of olfactory receptors in the nasal cavity by a gaseous material (5). The material itself is often called an odorant. A flavoring material or flavorant is that substance which may be added to a product to bring about certain changes in its flavor as being detected by the senses of taste, smell and feel or touch. Aroma is defined as the odorous quality (generally desirable) of a substance when perceived by the nose in sniffing. Aroma is not necessarily part of the flavor quality of a product, whereas odor is one of the major components of flavor.

Some recent studies provide a wealth of information with regard to the olfactory apparatus and the mechanism of olfaction (6, 9, 25, 29, 52, 53, 56, 72, 74, 76, 80, 81). The olfactory mucous membrane is located in the upper part of the nasal cavity on portions of the turbinate and septum. Olfactory nerves are imbedded in a special olfactory epithelium with an area of about 2.5 cm^2. The nerve fibers reach processes of olfactory bulb cells in the brain. Glands that secrete fluid are present in the nasal cavity. When an odorous compound (an odorant) travels through the nasal cavity a stimulus is applied to the nerve fibers. A wave of negative potential travels along the outer surface of the nerve to the sensory center (olfactory bulb) in the brain

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where it is discharged and a response is recorded. The exact mechanism of smell lies in the code by which the characteristics of the molecule are transcribed into nerve information. There have been many theories trying to explain this mechanism. In the most recent one (25, 56) it is stated that there are three types of olfactory receptors working in series. The first are the enzymes playing the part of reconnaisance sites. The second are the carrier proteins (a sort of chemical messenger) producing the electrical impulse to pass to the brain. The third are the receptor molecules which are responsible for "informing" of the odor. Proteins play a major part in the olfaction process, because the mere production of an electrical potential could hardly be considered as the only instrument of odor differentiation.

After a response is recorded in the brain, the nerve becomes completely insensitive for about .001 second (fatigue) and it regains its original sensitivity after about .01 second. Fatigue to odors is selective, that is, the olfactory system may not be able to respond to a certain odor stimulus for a short period of time, but its response to another odor stimulus (at a different potential) is unimpaired. The human olfactory system is a truly physico-chemical laboratory in miniature and can distinguish, with extremely high selective ability, tens of thousands of different odors through millions of specialized receptors.

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It is generally acknowledged that the senses of taste and smell (gustation and olfaction) are closely bound together; neither sense can be entirely isolated from the other. In fact, one needs his nose as much as his palate, and if one were deprived of his sense of smell he might confuse the taste of sugar and salt in solution (56). When attempting to describe or analyze taste, it is fundamental not to isolate the taste too much. One should not integrate an odor into an assembly of sense mechanisms which may pass far beyond the simple framework of gustatory-olfactory (flavor) perception.

A recent study (76) has concentrated on the flavoring action of certain nonvolatile compounds. Traditionally, these have incorrectly been regarded as simple nutritional elements. One must attribute a flavor of a product (as smoke) to a whole assembly of complex mixtures which are not limited to the four primary tastes. They constitute a subtle balance between the nonvolatile bodies of the particular taste (small in number and large in mass) and the volatile bodies responsible for the odor (large in number and small in mass). A third class of compounds acts as a taste-modifier or a flavor potentiator between the first two categories. Potentiation is akin to synergism, which is a cooperative action of discrete agencies such that the total effect is greater than the sum of the effects of each alone (38). While, to a chemist, the concept of volatility versus nonvolatility is clearly understood, to

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the sensory analyst the problem of volatility is less discrete since nonvolatile compounds also contribute to the perception of taste and odor. It is generally agreed that a substance acting in the nose (through the mouth) is volatile and one acting on the tongue and in the mouth cavity is nonvolatile. It has been confirmed (16) that some compounds which boil as high as 200-300°C can contribute to the total flavor by enhancing the odor characteristic. For example, β-phenylethanol which boils at 206°C does have an odor and in fact it is believed to contribute to the flavor characteristic of flue-cured tobacco (45) and baked bread (16).

2.2.3 Feel or Touch

The tactile factor is one of the components of the over-all sensation of flavor. Some compounds not only stimulate taste receptors and/or olfactory endings, but also that of the trigeminal nerve (a nerve with endings in the skin of the tongue and top of the mouth) giving a general sensation often described as "mouth feel" (5). Feeling sensations do not have a specific organ to register them. Ammonia is a common substance that stimulates the trigeminal nerve. In fact, ammonia has an odor but still it elicits a feeling sensation known as "tingling" or "sharp" (1). Other feeling factors contributing to the over-all sensation of flavor are "hot", "peppery", various kinds of irritation, numbing, astringency and harshness. The cooling effect of menthol is

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specifically a feeling factor which contributes the major role in the sensory appreciation of menthol.

2.2.4 Smoke Flavor

Quite apart from theories and hypotheses explaining the mechanisms involved in the senses of gustation, olfaction and feeling, flavor (in terms of taste, odor and feel or touch) is above all a characteristic of a product whether food, drink, or smoke.

During smoking, and as a puff is taken into the mouth, it is the multicomponent smoke aerosol that comes in contact with the receptor cells in the taste buds. The aerosol itself (or the aerosol partly dissolved in the saliva--it is not known which) stimulates the nerve endings and impulses are transmitted along nerve fibers to the brain. It is clear that the "information" determined in the brain in terms of a psychophysiological response is extremely difficult to explain categorically (62). The saliva washes the smoke out of the tiny well of the taste bud until the next puff is taken.

Meanwhile, as the puff is taken into the mouth, part of the smoke escapes, momentarily, to the nasal cavity; the large part being exhaled later through the nose. It is not known whether the particles and gases of the smoke aerosol dissolve in the fluid on the lining and the solution stimulates the olfactory cells or that the hairs of the cells penetrate the mucous and come in contact with the smoke aerosol. In either case, the nerve transmits an impulse (or

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simultaneous impulses) and the brain registers or "recognizes" a certain odor or different odors. In addition, the feeling factors are registered at the same time. The composite of all three sensations (taste, odor and feeling) is what gives rise to the integrated reaction that is smoke flavor.

It is important at this stage to distinguish between tobacco aroma and smoke odor as employed by the sensory analyst. Tobacco aroma is recognized as the tantalizing and delectable prelude to smoking, whereas smoke odor (as taken by mouth) is part of the flavor components of smoke. While smoke free of odor does not exist, one might suppose that odorless smoke would taste rather flat and uninspiring since all the subtle nuances of the flavor complex are not present. Feeling factors are noticed on lips, tongue, mouth cavity, throat and nose and without these much of the entertainment of smoking would be lost. Again, the palate, olfactory and feeling senses are very closely bound together and it is their combined function of registering the various smoke impressions that initiates the smoking enjoyment.

In a recent study on the flavor components of burley tobacco (68), 105 compounds were identified. Although many of these compounds contributed to the flavor of burley, none of them alone possessed the flavor characteristic of burley. Hence, it was presumed that this flavor is a quality derived from the interaction of these components and probably many

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others not yet identified. In a previous study (14), the steam volatile neutral substances in smoke of blended and unblended cigarettes were found to be, in decreasing amount, in flue-cured, Turkish, burley and Maryland. Data showed that the smoke from blended cigarettes has less of such neutral substances than would be expected if each tobacco in the blend contributed to the total in an additive fashion. The relative amounts of neutral substances were studied (77) in smoke from bright-leaf tobaccos of different aromaticities. Findings on the relative flavor of cigarette smoke showed some tendency towards a relationship between higher boiling neutral substances and smoke flavor, although no correlation was apparent, when total neutral substances were evaluated. A further study (78) was undertaken on steam-volatile acids in the smoke of cigarettes having different organoleptic (sensory) properties. There was no consistent relationship between flavor and total amounts of acids, though a tentative tendency towards a relationship existed between relative tobacco aroma and certain volatile acids.

In conclusion, it may be said that there is some correlation between the flavor or sensory properties of cigarette smoke and its content of some volatile oils and "tar" elements, particularly resins. However, it is quite probable that other elements (chemically nonvolatile) participate in the formation of smoke flavor. Even proteins, which emit a very unpleasant odor upon burning, can in small quantities constitute a positive harmonizing element in the

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composition of smoke flavor. Although many of the 1500 component substances of cigarette smoke are tasteless and/or odorless, most of them can be considered as potential sources of sensory properties in smoking (77, 78). For example, it has been confirmed (52, 53) that sub-threshold concentrations of many odorous compounds (and even some nonodorous compounds) can produce a detectable odor when intermixed. Thus the identification of the volatile constituents of cigarette smoke is not sufficient to determine its characteristic odors. Also, there is no assurance that compounds which do have an odor (in the pure state) actually do contribute to the smoke odor--during the actual smoking process--due to pyrolytic degradation and possible synergistic or antagonistic effects. Smoke flavor is dynamic, e.g. the grossly different odors of the so-called "fresh" and "stale" cigarette smoke.

Smoke reaction constitutes the principal difference between cigarette smoke and cigar smoke. While cigar mainstream smoke (as well as sidestream) is alkaline, has a bitter taste and thus not inhaled, cigarette mainstream smoke has a slightly acidic reaction (though sidestream is alkaline). There is a considerable confusion as to the term strength (or mildness) as applied to cigarette smoking. The physiological strength of cigarette smoke is dependent primarily on its content of nicotine and not on the degree or intensity of harshness, irritation and biting of the smoke which is a psychophysical strength (1) previously

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called "taste-strength" (73). Taste-strength is closely dependent on the smoke reaction, particularly the existence of ammonia and phenols. A higher smoke alkalinity is always associated with some psychophysical discomfort upon the senses of taste and smell, and hence the smoke is described as "strong". An acidic smoke does not produce strong sensations but only slightly "sharp" or faint "burning" ones. Although nicotine does not produce a specific recognizable psychophysical sensation, it does have a specific physiological effect which is the main reason why a person continues to smoke.

From an earlier investigation (69) the author stated that the various sensations recognized during the act of cigarette smoking are perceived (a) on the palate and top of the mouth, (b) the mouth cavity, olfactory organs and nasal zone, and (c) the respiratory system (throat, bronchial tubes and tips of the lungs) which registers the intensity of smoke and the gamut of its physiological strength. In addition to the flavor characteristic and physiological effect of cigarette smoke, there exist various irritants registered (recognized) in the respiratory organs, palate-tongue area and nasal zone. Irritation sometimes creates a purely physical discomfort which does not express the character of the smoke. Irritant sensations are part of the over-all sensations involved in smoking (1, 70, 73). Irritant sensations are normally of fleeting nature--disappearing immediately after the smoke has been exhaled.

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Of course, there are various peculiarities of taste other than the four primary ones--such as "clean", "neutral", "dry", "cavendish", "medicinal", etc. These are slang terms, commonly used and have meaning in the trade, but are meaningless to an outsider. They are usually separated into generally positive or desirable or generally negative or undesirable. The various odors (of different intensities) are likewise separated into positive or pleasant and negative or unpleasant. Odor sensations are much more difficult to isolate, define, and describe than taste sensations.

2.3 Sensory Testing of Smoke Flavor

Many attempts have been made objectively to define and/or to determine the chemical constituents of leaf tobacco and smoke that may contribute directly to the over-all sensory properties or smoke flavor (14, 66, 68, 73, 77, 78). Analytical methods are available for the determination of many component substances in the leaf and/or smoke that may contribute to smoke flavor; however, the results of these so-called objective methods have failed to establish a direct correlation between a single component (or a group of components) and the actual smoke flavor as determined by the sensory appreciation of the smoker. With over 1500 components identified in cigarette smoke, the idea of establishing a correlation between some selected components and smoke flavor seems an oversimplification.

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Objective methods can be more precise and more easy to calibrate, but a priori they cannot be more accurate than subjective methods; because the only way for validating an objective method is by correlation with subjective data (40). There are limitations to the so-called objective (instrumental) methods of measuring flavor components of a certain product. For example, any gas-liquid chromatography (GLC) detector responds as readily to nonodorous as it does to odorous compounds. Moreover, a detector can always fractionate and show concentrations of individual compounds but it cannot "sense" the effect of a "blend" or group of compounds in making odors. Some odorants at concentrations below detection threshold can in combination produce an odor. On the other hand, the sensitivity of the human nose, as a combination of all its internal aerodynamics and far reaching complex structures, is 1000 times greater than that of the most refined techniques of modern chemistry (52).

Workers on flavor determination have acknowledged the necessity of employing both the multi-instrumental (objective) and the quantitative human response systems. As a result of the recent developments in psychophysical procedures, experimentations with the three-fold requirement (isolation, variation and repetition) can be applied to the assessment of human sensory testing. The findings can be evaluated by the same criteria of validity and reliability employed in objective phenomena (25). The great inherent variability within each subject (individual) makes it

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difficult to trust individual response; hence, the need for the pervasive use of panels of subjects in sensory testing. Each panelist has certain limitations, however, if these limitations are recognized, a panel serves admirably. The limitations of individuals will be averaged in the over-all response and the panel could serve essentially as a laboratory tool with the necessary degree of precision obtained by replication. It is essential to distinguish between the use of a panel selected to discriminate in certain aspects and the use of a random sample of a population to establish consumer preference (51).

There is a considerable number of studies on sensory testing panels, commonly called "taste panels" (1, 5, 12, 13, 17, 18, 19, 20, 41, 46, 55) with respect to panel selection, training, screening, classification and evaluation. Most, if not all, studies cover the use of a panel in the sensory testing of many diversified commodities such as milk, beer, wine, cheese, bread, etc. As a general rule, a panel is selected, trained and used on the basis of requiring that the individual panelist should be able either (a) to detect flavor difference or (b) to detect flavor difference, characterize the nature of the difference and scale its intensity.

Panels are classified according to: (a) the kind of product the panel is testing, e.g. milk, beer, wine, etc. and (b) the type and degree of training of the panelists. With respect to training, panels can be classified into

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four main types: untrained, semi-trained, trained, and highly trained or expert panels. Members of untrained panels are chosen to represent a segment of population to carry out preference or like-dislike tests on some finished product to determine which one is to be introduced in the market for consumer acceptance. Untrained panels are large in number, having 80 or more members.

A semi-trained panel consists normally of about 50 members who are employed in detecting differences as well as indicating preference among samples of a finished product.

Trained panels are mostly used as a laboratory tool in research and development. A trained panel usually consists of 15-20 individuals who received training to increase their sensory acuity, improve their discriminating ability and make them acquainted with the degree and type of differences to be tested and the method of testing. A trained panelist is selected after passing a series of screening tests, thus demonstrating some discriminating ability beyond the chance probability.

A highly trained panel consists of 4-7 "experts" who can make a complete flavor profile analysis of a product (or a raw material) and give a complete description of its quality as well as diagnostic recommendations for its improvement.

In general, the type and amount of responsibility to be assigned to the panel dictate the degree of training the panelists have to acquire. On the other hand, the type

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of training determines the way in which the panel is to be used.

A considerable number of studies (5, 12, 46) stress the value of training panel members. Training should be based on the criteria (e.g. product and type of differences) which the panel will be using during the actual testing or evaluation; however, primary taste testings can be used to familiarize the subjects with the four primary taste qualities. In general, training increases the subject's sensory acuity and makes certain that the panel has uniform understanding of the product and types of differences to be evaluated, the system of evaluation and the relationship between various intensities and/or qualities of certain stimuli. A trained panelist is more accurate and reliable and, therefore, can detect and describe differences which are unheeded by the untrained.

There is a great paucity of published information on selection and training of panels for use in cigarette smoke evaluation. In a distressingly large number of studies on or related to panel evaluation of smoke flavor (14, 45, 54, 68, 78), the psychophysical method used is not even reported. Moreover, no information is given with respect to the criteria of measurement, the type of panel, and the degree of training involved. The results of smoke evaluation are often expressed as preference, e.g. "seven out of 10 panelists preferred the treatment over the control", or descriptive terms (vocabulary), e.g. the panel described the

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smoke of the treatment as "full", "sweet", "mellow", etc., whereas that of the control to be "flat", "harsh", "biting", etc.

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3. EXPERIMENTAL ARRANGEMENT

3.1 The Size of Panel

As a general rule, the panel size is determined by the number of panelists necessary to secure a desired level of statistical significance for the sensory tests to be undertaken (12, 20, 41). Hence, panel size depends entirely on the kind of panel and what type of sensory tests the panelists will undertake. In planning the experimental work it was decided that a trained panel consisting of about 20 individuals would be required to evaluate cigarette smoke of experimental tobaccos. It was also decided that for any given sensory test 15 to 20 panelists should be employed with enough replications per panelist to achieve the desired precision. To be able to have 20 "active" panelists participating in each sensory testing experiment, at least 30 individuals should be selected and trained. The assumption is: although there exist 30 selected and trained panelists it would be almost impossible to have them all available to carry out a particular sensory testing experiment within a reasonable period of time. One of the major problems in sensory testing is that the measuring device (panel members) is not available at all times. Some panelists may discontinue and/or may not be available (deliberately or because of some physical indisposition, e.g. cold, sinus, etc.) when needed for testing.

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3.2 Selection of Candidates

After deciding that at least 30 panelists should be selected and trained to end up with a panel of the desired size, the next step was to ask for volunteers. Some 150 questionnaires were distributed in the summer of 1972 among the faculty and staff in the nearby buildings (to secure availability and time saving). The number 150 is arbitrary. Each questionnaire was accompanied with a letter from the Assistant Director of Tobacco Research explaining the objectives of the research program and asking for volunteers to serve as potential panelists. Informing the people of the importance of the research program and the contribution it would make presumably increased each individual's motivation and stimulated his interest in participating in the sensory project (Appendix Figures 1 and 2). Ninety-three individuals responded. Pertinent statistics concerning each volunteer, particularly with regard to age, sex, smoking habit (if any), years of smoking, etc. were supplied by the questionnaire (Appendix Figure 3). The 93 volunteers constituted a heterogeneous group of individuals consisting of non-smokers, cigarette smokers, pipe and cigar smokers, different ages and both sexes.

At this stage a decision had to be made whether to consider the 93 volunteers as candidates or to select from among the volunteers a particular group of individuals (say, smokers) who would be considered as candidates.

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Various publications (5, 12, 20, 41) on panel selection techniques indicate that candidates should preferably be regular consumers of the product that they will be testing, however, these publications covered the testing of such products as wine, milk, meat, beer, etc. To date there are no published studies to support the hypothesis that individuals who are non-smokers should not be accepted as candidates for a smoking panel. Consequently, all the 93 volunteers were considered as candidates. The null hypothesis was made that all the 93 volunteers have an equal chance to become panelists.

Since the experimental tobaccos were to be flue-cured, which are used mostly in cigarettes but also can be used in pipe and even cigar, both cigarette smokers as well as pipe and cigar smokers can be accepted as candidates. Another argument is that non-smokers may be considered as potential smokers as long as they agree to participate in smoking tests. Further, the experimental tobacco may be a completely new variety, e.g. low tar and nicotine, or new type, e.g. stemless cured, on which a thorough investigation relative to its sensory appreciation by the general public might be required.

A personal letter (Appendix Figure 4) was sent to each of the 93 candidates expressing appreciation for his (her) willingness to cooperate and asking the candidates to indicate the time(s) during the week he (she) might prefer to be available. A candidate's participation required no

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more than 30 minutes per week (divided into 2-3 visits to the laboratory) and the time schedule was made so as to interfere minimally with the candidate's regular duties. Though not compensated, all candidates understood that participation was a fully-sanctioned activity.

3.3 Testing Conditions

All tests were conducted under standard conditions in the newly constructed Smoke Evaluation Laboratory to control or standardize the various extraneous variables by which the subjects may be influenced (deliberately or by chance).

Recent developments in psychophysics (25, 28, 29, 30, 31, 62, 79) have made clear the extremely important role of testing conditions or environment on the effectiveness of the sensory mechanisms. Psychophysics concerns the functional relation between stimulus and response (79). In other words, psychophysics is the quantitative study of the relationship between stimuli and the sensations obtained in experiments with human subjects. Psychophysics has been an interdisciplinary field which is as much a part of physiology and physics as is psychology, in addition to statistics and mathematics.

An earlier study (28) defined the stimulus-response (S-R) relationship as a sequence of four momentary sensory properties: detection, recognition, discrimination and scaling. These sensory properties are perceived momentarily as one response or one "signal" detection.

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There are two theories of sensory detection: the classical theory of threshold and the contemporary theory of "signal" detection. Both theories agree that the detection task is influenced by variability or "noise" but both accounts of the variability are basically different. According to the threshold theory, the magnitude of the response varies with the intensity of the stimulus, the sensitivity of the receptor, the efficiency of the neural connections and the background activity of the center of the brain. In the detection theory, the stimulus has an effect but its effect must be assessed against the effects of extraneous non-stimulus variables or "noise" which also have perceptual effects. "Noise" may be contributed by the subject, the test conditions (environment), or spontaneous activity of the sensory system; it may be introduced on purpose or it may be a result of variability in the stimulus (because of the lack of physical control over the amount of the stimulus actually reaching the subject's sensory receptors).

The inaccuracy in determining a subject's detection level for a given stimulus will exist as long as there is no standardization or control of the extraneous variables. According to the subject's criterion he may respond to a given stimulus in a given trial but he may not respond to the same stimulus in another trial. Since the effect of the criterion is independent from the stimulus effect, it is important to control the criterion in order to get consistent

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responses over repeated trials. Moreover, the difficulty in comparing sensory testing results from different laboratories will not be resolved as long as the comparison is made in terms of one selected concentration value per stimulus without control of non-stimulus variables. A rigid control of testing conditions is an important and necessary adjunct to any serious research involving sensory testing.

A proposal for the construction of a Smoke Evaluation Laboratory was approved in July 1971. With total renovations the assigned space was partitioned into a smoke evaluation room, a sample preparation room, a storage area, and an office (Appendix Figure 5). The smoking room (Figure 3.1) was equipped with six partitioned booths and a conference table with six chairs. The booths were designed in such a way that the opened doors served as partitions between panelists during smoking tests. Opening the door automatically operates the exhaust fan and turns on the overhead light. When the booths are not in use the doors can be closed to provide enough space to use the smoking room as a conference room (Appendix Figures 6, 7 and 8). The laboratory was equipped with wall-to-wall carpet (for appearance and noise deadening) and attractive light fixtures. The walls were painted in off-white. The booths were built with matching panelling. The main idea was to create a pleasant relaxing atmosphere with minimal distraction. The laboratory was always kept clean, odor

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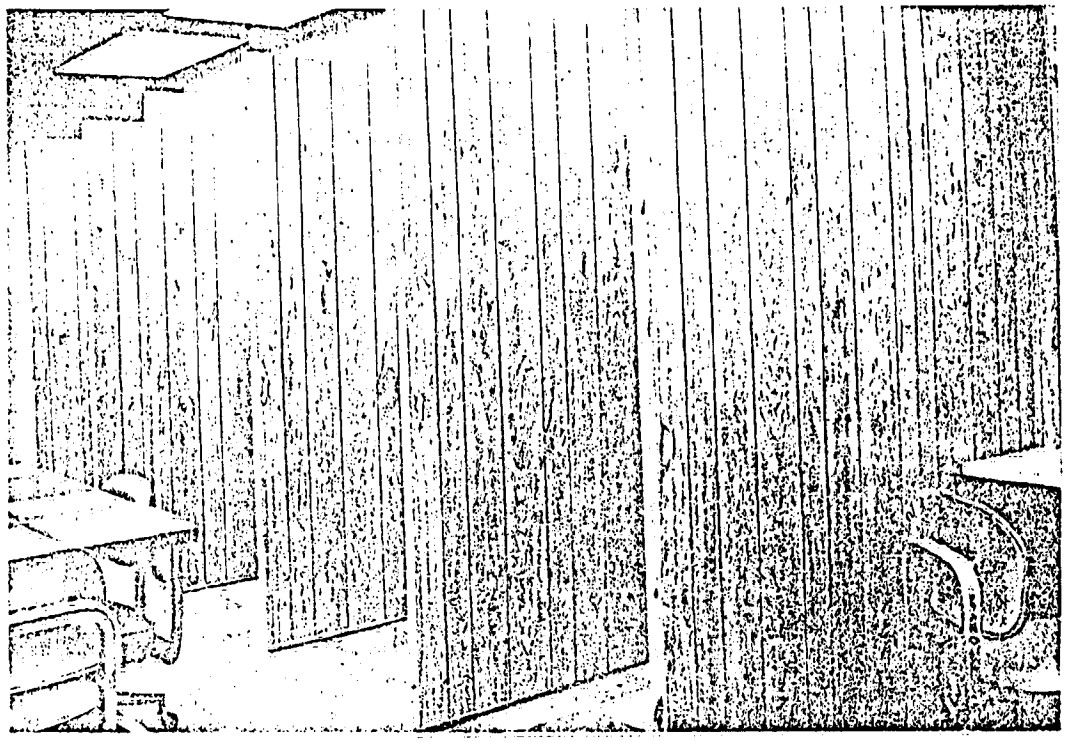

Figure 3.1 Smoke Evaluation Laboratory showing booths in the open configuration

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free and at a standard temperature and relative humidity, approximately 70° F and 60%, respectively. The laboratory was completed and ready for use in sensory testings in June 1972.

3.4 Testing Methods

A considerable number of publications is available on sensory testing methods (1, 5, 17, 18, 20, 24, 29, 42, 54). The various methods of sensory testing can be classified into five groups: difference tests, analytical tests, sensitivity tests, ranking tests, and rating tests. Within each group there are several methods by which the test can be conducted.

The selection of a sensory test method depends entirely on the defined objective of the test. The method should be appropriate to the problem and situation, it should be efficient and practical and, also, it should be as simple as possible. No one method can serve all purposes and it might be wise to investigate several approaches before selecting one. In addition, sensory problems are becoming so specialized that it is sometimes unfruitful to follow the exact procedure of another worker who may have had different objectives, products, situations or subjects.

A proper sensory testing methodology requires that both the experimental design and the method of statistical analysis be considered at the time of planning the sensory tests. For example, there are assumptions about the error

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structure that have to be satisfied in order to be able to use the analysis-of-variance procedure in the statistical analysis of data from sensory testing (3, 13, 15, 23) -- variables submitted for panel evaluation and observations obtained must be independent and normally distributed, homogeneity of error and the additivity of the effects of test comparisons and testing conditions. It has been stated (48) that because of the multiplicity of test purposes and testing techniques it is impossible to recommend one or two methods of analysis of data from sensory testing. A review on the statistical methods applied to data from sensory testing (82) covered the mathematical formulations used in difference tests and preference tests for two or more samples. Earlier studies (13) indicated an existing gap between theories of statistical methods and application of such to sensory testings. The reasons given for the gap are (a) the general lack of mathematical training of sensory analysts and (b) a lack of understanding the basic principles of psychophysics by the mathematical statistician. In another study (37) the author discussed the theory of paired comparison and its contribution to sensory testing and quality evaluation, and concluded that a paired-comparison scheme is more objective than ranking or preference.

The primary responsibility of the potential panel is smoke evaluation of experimental tobaccos. In most cases the panelists will be comparing one or several treatments (representing new varieties, cultural practices, curing

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methods, etc.) and a control or standard. The panel will presumably be asked to supply some information with respect to the existence of a difference in smoke flavor and the intensity of the difference. Hence, the subjects should be trained on how to detect differences and the panelists should be selected on the basis of their discriminating ability to detect differences. The decision was then made to employ difference tests, and in some cases sensitivity tests, in all the sensory tests to be conducted.

In addition to the philosophy of measurement (difference, sensitivity, analytical, etc.), there is the methodology by which the measurement is taken. The most common methodologies employed in difference tests and/or sensitivity tests are the so-called triangle method and paired-comparison method. The triangle method uses three entities, two the same and one different. The subject is asked to pick out the odd. The paired-comparison method uses only two units, and the subject is asked if there is a difference. Psychologically, paired-comparison method oftentimes introduces a response-bias (5, 25, 62). It is well known in psychology that a subject's expectation of what will happen will introduce a response bias for him to "perceive" it. Such instructions as asking the subject to report whether there is a difference or not might well instill in the mind of the subject the sensory analyst's expectation that there is a difference. The same effect may occur when the subject is asked which one of a pair has

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greater intensity of a certain flavor. The ideal situation is when the subject has his own concept of the situation, but sometimes the subject develops one during the course of the experiment and responds accordingly. Psychologically, the problem is not that seeing-is-believing but sometimes the other way around.

An interesting study on the role of psychophysics in sensory testing methods (62) indicated that the triangle method is especially useful with complex flavors or products where the nature of the flavor quality is difficult to specify. In a triangle test it is not necessary to specify dimension or description (no preference should be asked) and the subject merely indicates the odd entity if he can. For these reasons, the decision was made to employ the triangle method in all the smoking tests conducted for panel selection, training and use. In methodological tests for determining degrees of intensity in some simple property, e.g. the subject is asked to select the stronger of two or more sweet solutions, the paired comparison is superior to the triangle. In other words, when the stimulus dimension is known and concentrations can be manipulated (as in primary taste testing) the triangle is an added complication and the paired comparison is preferred. But, when the dimensions are complex as in cigarette smoke, then the triangle test has good applicability.

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4. PRIMARY TASTE TESTING

4.1 Introduction

Most people know that candy is sweet and that they prefer their tea "sweetened". Few if any have ever experienced the taste of a pure, weak solution of sucrose. Thus the primary objectives of the taste testings were to familiarize these inexperienced volunteer subjects with the primary taste qualities -- sweet, salt, sour and bitter -- and to impress upon them that the different taste stimuli are sensed in different regions of the palate. Sweetness is detected mostly on the tip of the tongue; saltiness is sensed on the sides and tip of the tongue; sourness mostly on the sides, and bitterness on the back of the tongue and on the pharynx.

Theoretically, a subject who both recognizes the primary tastes and knows the right positioning of each taste sensation in relation to his taste organs would presumably perform more discriminatingly during the actual smoking tests.

A subject's performance in these primary taste tests in no way compromised his potentiality for selection as a panelist.

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4.2 Materials and Methods

4.2.1 Threshold Determination

One of the well known tools for measuring human taste sensitivity is the determination of the detection threshold

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$(DL)^2$ and the recognition threshold $(RL)^2$. The most common psychophysical method for determining a subject's threshold (DL and/or RL) is the method of limits (62).

In using the method of limits, specified concentrations of a taste solution are presented in successive order, with an alternating sequence of increasing (or decreasing) concentrations. Each transition point in an ascending (or descending) series marks a threshold, e.g. when the subject experiences a change from "no response" to "response" in an ascending series. The method of limits was used in determining the subject's detection thresholds and his recognition thresholds.

4.2.1.1 Sample Preparation. Sample solutions were prepared of sucrose (sweet), sodium chloride (salt), tartaric acid (sour) and caffeine (bitter), each at 14 different concentrations (Appendix Table 1) in double-distilled water. Solutions were stored in glass-stoppered pyrex bottles at room temperature (Figure 4.1). Solutions not used within 72 hours were discarded and replaced with fresh solutions.

4.2.1.2 Sample Serving. At each test, a series of nine concentrations of the particular test solution was presented to the subject in odor-free disposable plastic medicine cups along with the printed instructions and the response card.

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[2]The letter "L" stands for the Latin word limen which means threshold.

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Figure 4.1 Serving of taste solutions for primary taste testing

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The cups were arranged on the serving tray in order of increasing concentration from left to right and labeled 1 through 9. The reference solution was always double-distilled water. Additional double-distilled water was provided for continued rinsing of the mouth between successive tastings. All solutions were served at room temperature and all taste testings were taken in the booths under temperature-humidity regulated atmosphere, approximately 70°F and 60% relative humidity (Figure 4.2).

4.2.1.3 Test Procedure. A subject was requested not to have eaten or smoked within 20 minutes prior to presenting himself for a test. Only after having carefully read and understood the instructions (Appendix Figure 9) was he allowed to proceed deliberately with the test. Starting with distilled water in the left cup, he then tasted the first solution, spitting it into a waste receptacle and rinsing his mouth with distilled water before moving to the next. He recorded his detection threshold (DL) by circling the number printed on the response card (Appendix Figure 10) corresponding to the number labeled on the cup containing the solution first detected as tasting different from distilled water. The first solution in which the taste could be recognized (recognition threshold, RL) as sweet, salt, sour or bitter was similarly recorded on the response card.

Each of the primary taste series was tested three times by each subject. In successive tests the entire series was

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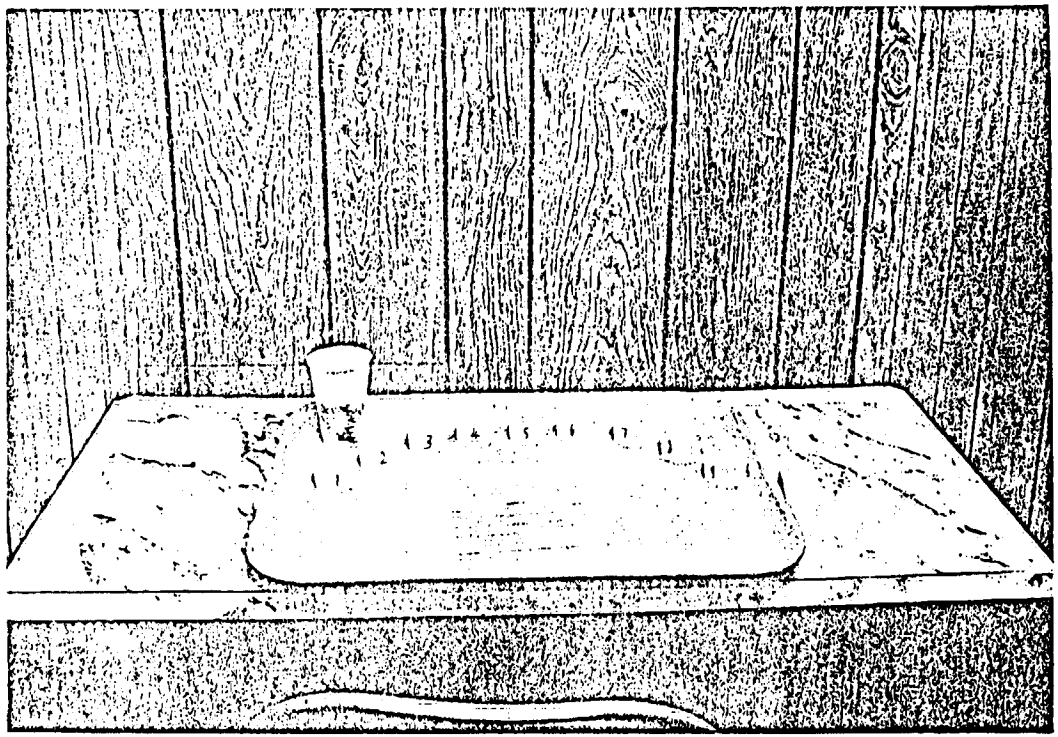

Figure 4.2 Presentation of primary taste solutions for determination of taste threshold by the method of limits

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shifted to a higher or lower concentration (so that a particular concentration did not appear in the same position in any two given tests) to avoid the possibility of a position bias in the subject's response.

4.2.2 Measurement of Acuity Value[3]

Having determined the mean threshold, a sensory analyst should proceed to determine the acuity value which is a more meaningful measure of the subject's taste sensitivity. A subject's threshold may be considered as a tool to measure taste perception, whereas a subject's acuity value reveals his ability to recognize and discern some predetermined absolute or relative differences as well as his ability to duplicate his own findings (reliability).

The most reliable and informative method for determining a subject's acuity value is the ranking method (49, 75). The subject is presented with a series of 5-9 taste solutions in random order -- consisting of 2 to 4 solutions in concentrations below his average recognition threshold (RL) and 2 to 4 above -- and he is asked to arrange (rank) them in order of increasing concentration.

4.2.2.1 Sample Preparation and Serving. Certain of the same solution concentrations that had been prepared for threshold determination were used in the acuity tests.

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[3]Acuity measures a subject's ability to rank concentration increments.

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In the acuity tests, the subject was served (Figure 4.3) concentrations of a particular taste series; one being his previously determined recognition threshold, two higher concentrations and two lower concentrations. These, in medicine cups labeled with code numbers, were presented in random order along with the instructions (Appendix Figure 11) and response card (Appendix Figure 12).

4.2.2.2 Test Procedure. The subject's task was to rearrange the solutions in order of increasing intensity (concentration) and to record the coded identities in the same order on the response card. The test was repeated three times, for each taste quality, using different code numbers.

4.3 Results and Discussion

4.3.1 Threshold Values

Appendix Table 2 presents the threshold (DL and RL) values expressed in mM/l for each subject who completed the three tests. Each value is an average of the three tests. A summary of these results in terms of general means for all subjects in all taste tests is shown in Table 4.1. It is clear from these results that recognition thresholds tend to be higher than detection thresholds. The means for recognition thresholds are about two times higher than for detection, however, the ranges for the two thresholds are overlapping. Thresholds (both DL and RL) can be arranged from low to high, sour, bitter, sweet and salt -- that is,

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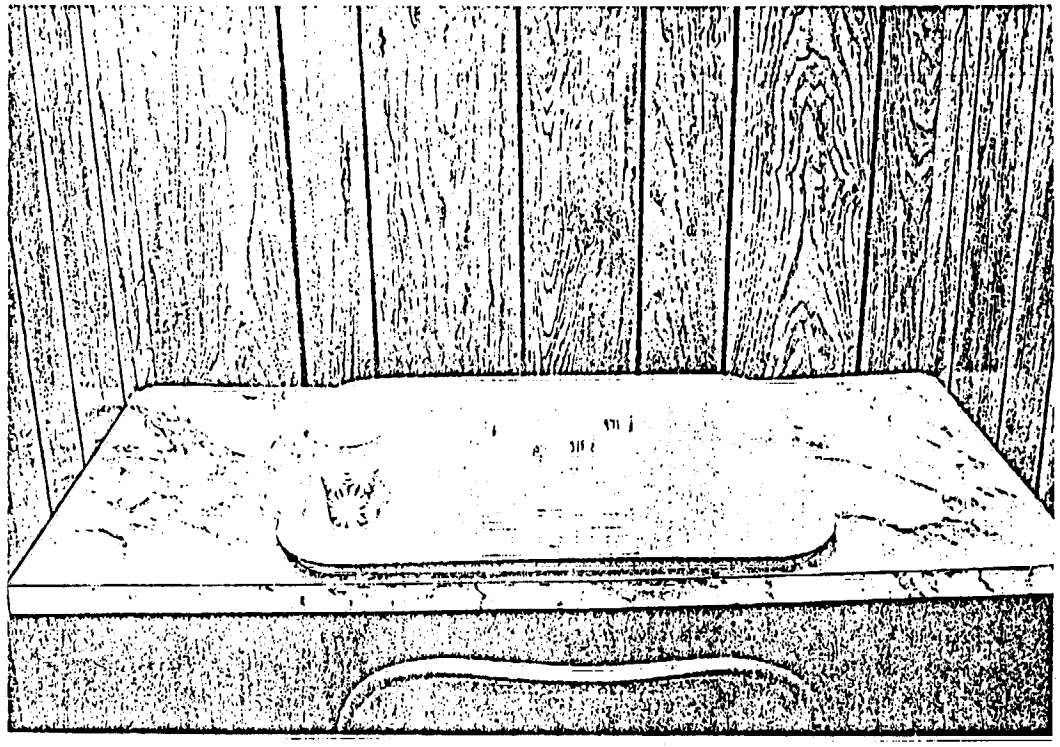

Figure 4.3 Presentation of primary taste solutions for the determination of the acuity (sensitivity) values by the ranking method

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Table 4.1 Subjects' mean and range of threshold values in mM/l for the four primary tastes

Substance	Primary taste	# of subjects	# of tests	Detection threshold (mM/l)		Recognition threshold (mM/l)	
				Mean	Range	Mean	Range
Sucrose	Sweet	32	96	4.6	2.5-10	12	5-20
Sodium chloride	Salt	32	96	5.5	2.5-15	14	5-20
Tartaric acid	Sour	31	93	.2	.1-.5	.6	.25-1.50
Caffeine	Bitter	31	93	.6	.3-2.0	2	.5-5.0

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subjects' taste mechanisms are more sensitive to sour and bitter substances and less sensitive to salt and sweet. The results of recognition thresholds in Table 4.1 are in agreement with data published recently (62) on the mean thresholds in man, using the same taste substances.

There is a proven difference in the efficiency per molecule of each taste stimulus, that is, taste buds are stimulated by the impingement of solute molecules and, within limits, the degree of stimulation is proportional to concentration (7). So long as one is concerned but with one stimulant solute (one taste substance), any unit of concentration is satisfying. But for comparing different taste substances molecular concentration should be used -- a 2% solution of NaCl contains 6 times as many molecules per unit volume as 2% sucrose solution, but a 10 mM/l concentration of both contain the same number of stimulus molecules. Thus to compare threshold values from different laboratories, there should be a standardization of methodology, taste substances and solution concentrations. Moreover, since the ultimate understanding of how the stimulus works is in physico-chemical terms, molarity was the unit of choice in specifying concentrations.

4.3.2 Acuity Values

The acuity value for each subject in each ranking test was computed as the rank correlation coefficient which is a measure of the correlation between the correct ranking and

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the subject's ranking of the taste solutions. The acuity value can be determined as Spearman's rank correlation coefficient or as Kendall's τ. Kendall's τ takes little longer to compute but its frequency distribution on the null hypothesis is simpler and it can be extended to study partial correlation (75). A subject's acuity value in terms of Kendall's τ is

$$\tau = 1 - \frac{Q}{n(n-1)}$$

where Q = number of rank inversion by the subject compared with the true rank and n = number of solutions. Kendall's τ is considered an appropriate measure of one's sensitivity and reliability.

Appendix Table 2 shows the acuity values in terms of Kendall's τ for the 25 subjects who completed all three acuity tests. Each value is the average of three tests. A summary of these results is given in Table 4.2 which shows the general means of acuity values for all subjects in all taste tests. Theoretically, the acuity value ranges from -1 to 1; with the value 1 implying the highest sensitivity or perfect ranking.

The data in Table 4.2 indicate that, on the average, the subjects' sensitivity to the sour taste is much greater than that for bitter, salt and sweet tastes. Moreover, some subjects are more sensitive to one taste quality than to another but all subjects seem to be sensitive to sour taste (as indicated by the smaller standard deviation, .07). The subjects' sensitivities to sweet taste are much less than to

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Table 4.2 Subjects' mean and range of acuity (sensitivity) values as Kendall's τ for the four primary tastes[a]

Substance	Primary taste	# of subjects	# of tests	Acuity value (Kendall's τ) Mean	Range	SD[b]
Sucrose	Sweet	25	75	.789	.40 - 1	.194
Sodium chloride	Salt	25	75	.853	.47 - 1	.164
Tartaric acid	Sour	25	75	.910	.67 - 1	.077
Caffeine	Bitter	25	75	.834	.53 - 1	.134

[a] τ = rank correlation coefficient

[b] SD = standard deviation

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the other taste qualities. Also, subjects vary considerably among themselves in their sweet-taste sensitivity (as indicated by higher value of standard deviation, .19).

Furthermore, when both correlation studies and Chi-square tests were made of the subjects' sensitivity to the four primary tastes in terms of acuity values, the results show that, in general, there is a significant correlation between sensitivity to sweet taste and sensitivity to salt, sour and bitter tastes individually (Appendix Tables 3 and 4). A subject who is sensitive to sweet taste (able to correctly rank sweet solutions) is most probably sensitive to salt, sour and bitter. It seems that those who have a higher discriminating ability among the sweet solutions presumably have less difficulty in tasting other taste substances (to which their taste mechanism is more sensitive by nature). However, three subjects had higher acuity values for sweet taste than for salt, sour and bitter.

4.3.3 Smoking and Taste Sensitivity

A t-test comparison of the mean recognition thresholds of 25 smokers versus six non-smokers (Appendix Table 5) showed that there is no significant difference between the two groups in their recognition threshold to the four primary tastes. Moreover, the t-test showed no significance difference between the two groups with respect to their sensitivity to the four taste qualities in terms of acuity values (Table 4.3). These results are not in full agreement

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Table 4.3 Paired-comparison between means of primary taste sensitivities of smokers and non-smokers

	Sweet		Salt		Sour		Bitter	
	RL[a]	τ[b]	RL	τ	RL	τ	RL	τ
Smokers	12.8	.72	13.9	.84	.57	.90	2.14	.82
Non-smokers	10.4	.82	15.9	.90	.83	.95	1.58	.88
t[c]	1.14	.43	.86	.81	1.99	1.74	1.11	.96
$t_{.05}$[d]	2.04	2.07	2.05	2.07	2.05	2.07	2.05	2.07

[a] RL = means of recognition thresholds in mM/l for 25 smokers and 6 non-smokers

[b] τ = means of acuity values (Kendall's τ; rank correlation coefficient) for 19 smokers and 6 non-smokers

[c] t = True value of t for the difference between two means

[d] $t_{.05}$ = Value of t significant at the 5% level

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with some previous findings (59) on taste sensitivities of smokers and non-smokers.

Some workers contend that smoking decreases taste sensitivity, reduces olfactory perception, and diminishes hunger contractions (59). Unfortunately, valid experimental evidence supports only a few of these claims, with a considerable lack of agreement among investigators. Within the last ten years, there has been a considerable number of studies on the interrelationship between cigarette smoking and taste perception (2, 26, 27, 34, 35, 36, 43, 47, 50, 60, 61, 63, 64). Results from one of the studies (43) indicated that the threshold for bitter taste is significantly higher in smokers (less sensitive) than in non-smokers. However, several studies failed to support a cause-and-effect relationship between smoking and taste perception (27, 35, 60, 61), whereas results from one study (36) showed an intriguing synergistic effect of aging and smoking. Either age or smoke alone does not dull taste responsiveness, but together they exert a progressive reduction in response to the bitter tasting compounds. In a recent study (2) the taste sensitivity of 32 male subjects ranging from 25-50 years of age and all smokers of 10 cigarettes or more per day was measured in terms of acuity value. The relationship between the acuity values and the subject's smoking "intensity" (defined as number of cigarettes smoked per day times number of years of smoking) was then established. Correlation coefficients indicated that smoking significantly reduced

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sensitivity to sweet and sour tastes, with a slight but insignificant reduction in salt sensitivity and a significant increase in sensitivity to bitterness.

To date, the influence of cigarette smoking on human taste perception is still subject to controversy for several reasons, of which (a) methods of measuring taste sensitivity vary considerably depending on the purpose of study and the preference of investigator, (b) a lack of standardization of both the terminology employed and the criteria for selecting the subjects involved, and (c) a lack of understanding of the complexity of cigarette smoke and its interaction with the sensory mechanism are most important.

The data in Table 4.3 were generated by a heterogeneous group of both sexes, of different ages, of different smoking habits, etc. The primary interest was the selection and training of a panel for cigarette smoke evaluation, and the main reason for conducting the primary taste was to familiarize the subjects with the four primary tastes and the correct positioning of taste sensations. Most, if not all, previous findings were based upon investigating the relation between taste sensitivity (threshold) of non-smokers and that of a selected group of smokers; one sex, at a certain age, smoke a certain product, at a certain rate, etc.

A further comparison was made using the threshold and acuity values of non-smokers with those of a selected group of smokers (2 females and 11 males, all over 21 years of age and all of whom smoke 20 cigarettes or more per day). A

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summary of the relationship is given in Table 4.4. The t-test shows that this particular group of smokers is significantly less sensitive to sour taste than the non-smokers. Appendix Table 7 shows details of the relationship between taste sensitivity of non-smokers and selected cigarette smokers.

Insofar as the interrelationship between cigarette smoke and taste perception, there are two different approaches by two separate research groups. Physiologists, psychologists, sociologists and food technologists are mainly interested in investigating the definitive manner in which cigarette smoke alters responses to taste stimuli of things other than smoke and, also, whether people with inherent differences in taste sensitivity are more likely to become smokers. Advances in electrophysiology have made it possible to record the nerve impulses from a single nerve fiber in a taste receptor cell, and perhaps this technique can be used in further elucidating the effect of smoke on taste perception.

On the other hand, tobacco scientists, technologists and sensory analysts are primarily interested in the sensory properties of cigarette smoke -- how is it perceived and how does it taste? Research in product development covers ways and methods of improving the taste properties of the smoke to make it more appealing to the smoking public. The selection and training of a panel for smoke evaluation of experimental tobaccos is an important part of tobacco research and product

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Table 4.4 Paired-comparison between means of primary taste sensitivities of selected cigarette smokers[a] versus non-smokers

	Sweet		Salt		Sour		Bitter	
	RL[b]	τ[c]	RL	τ	RL	τ	RL	τ
Cigarette smokers	14.1	.75	14.1	.87	.55	.89	1.96	.82
Non-smokers	10.4	.82	15.9	.90	.83	.96	1.58	.88
t[d]	.62	.61	1.61	.37	2.06	2.78*	.87	.80
$t_{.05}$[e]	2.11	2.16	2.11	2.16	2.11	2.16	2.11	2.16

[a]Those over 21 years old and who smoke 20 cigarettes or more per day

[b]RL = means of recognition thresholds (in mM/l) for 13 smokers and 6 non-smokers

[c]τ = means of acuity values (Kendall's τ; rank correlation coefficient) for 9 smokers and 6 non-smokers

[d]t = True value of t for the difference between two means

[e]$t_{.05}$ = Value of t significant at the 5% level

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development. During the process of panel selection and training, primary taste testing is conducted to familiarize the subjects with the four primary taste qualities. Oftentimes subjects are confused between such qualities as sour amd bitter, especially at low (near threshold) concentrations. Moreover, a subject's knowledge of the correct positioning of the taste sensations on his palate and pharynx will presumably improve his sensory acuity during the actual testing of cigarette smoke.

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5. PANEL SELECTION AND TRAINING

5.1 Introduction

The triangle method is a most appropriate one for use in determining a subject's ability to detect differences in such a complex product as cigarette smoke. As a general rule, it is wise to use the same number of trials per subject for each smoking comparison. Also, it is highly desirable to standardize and control the various dependent and independent variables by which the subjects may be influenced (deliberately or by chance) when the experiment does not require such influence. Recent studies (5, 12, 17, 18, 20, 24, 28, 31, 46, 62, 79) have emphasized the important role of both stimulus and non-stimulus variability on the performance of sensory testing panel. The main sources of variability (subject, situation, treatment and task) are summarized in Table 5.1 with respect to definition and typical variation or influence of each source.

Panel selection techniques should be designed not only to qualify subjects as panelists but also to train them on how to detect differences. In selecting (and training) a panel for use in evaluation of cigarette smoke of experimental tobaccos, one criterion must be emphasized: the differences in the test cigarettes must reflect in some way or another the kind of differences the panel will presumably be facing in the actual evaluation of experimental tobaccos.

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Table 5.1 Principle sources of variability in sensory testings (subjective responses)[a]

Experimental variable	Definition	Typical variation or influence
Subject	Individual in the experiment	Interest, motivation, sensitivity, training, experience, adaptation
Situation	Conditions of the experiment, equipment, facilities	Surroundings, physical method to control stimulus, experimenter-subject relationship
Treatment	Anything the experimenter does or gives to the subject	Order of presentation of samples, instruction, time and rate of responding, type of reports or response forms
Task	The problem or the test confronting the subject	Nature or form of complexity, familiarity, meaningfulness, duration of stimuli

[a]A tabulated summary of information given in a recent study (19)

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5.2 Materials and Methods

5.2.1 Design of the Test Cigarettes

The cigarette tobacco was made in four different lots reflecting in one way or another four different categories of smoking characteristics that would presumably exist dur the actual evaluation of experimental tobaccos. These fou lots of tobacco are specifically (Table 5.2):

Lot A. Cigarette of a flue-cured tobacco variety, Coker 254, grown at the Lower Coastal Plain Plain Tobacco Research Station, Kinston, N. C. in 1971. The tobacco underwent an accelerated aging process for six weeks before making into experimental cigarettes.

Lot B. Cigarette of a blend of tobaccos including the same flue-cured tobacco used in Lot A, burley, Maryland, and Turkish in proportions representing those prevailing in the average American blended cigarette.

Lot C. Cigarette of tobacco blend B but with casings (including sugar) in an amount equivalent to that usually employed in a blended cigarette added before manufacture.

Lot D. Cigarette made up of portions of cased blend C but with proper flavorings and top-dressings (similar to those used in blended cigarettes) being added before manufacture.

Tobacco, other than flue-cured used in the blend of Lot B, Lot C and Lot D, were provided by a cooperating company. Rag (cut) tobacco of each of the four lots was adjusted to 13.0 $\pm$ .5% moisture content prior to manufactur

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5.2.2 Cigarette Making and Marking

The method by which the experimental tobaccos were to made into cigarettes received great consideration during th

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Table 5.2 Experimental cigarettes for panel selection and training

Group	Description	% Moisture
A	Flue-cured var. C-254	13.15
B	Blend of A, burley, Maryland and Turkish	13.18
C	Blend of B with added casings (including sugar)	13.29
D	Cased blend C with added flavorings and top-dressing	13.47

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actual planning of the experiment. The making of the experimental cigarettes on a commercial cigarette-making machine would introduce a serious error unless certain precautions are taken. To obtain adequate cigarettes of proper "quality" the machine run must be of sufficient length to permit the machine to come to equilibrium even if the quantity of cigarettes actually needed for the smoking tests is much smaller. It had been demonstrated that 10 pounds of rag were sufficient for a proper run.

All lots of experimental cigarettes were made under the experimenter's supervision in the pilot plant of the Department of Products Development of a cooperating company. Cigarettes were checked to secure standard length, circumference, draw-resistance (pressure-drop), firmness and weight. Only those cigarettes with differences of less than 5% from the desired values were chosen. The cigarettes were made non-filter with 70 mm length. While making the cigarettes, two marks were printed on each cigarette, one 5 mm away from the "ignition" tip and the other 40 mm from the same tip.

After making, cigarettes were packed immediately in packets of 20's and the packets wrapped in cellophane and placed in cartons of 10's. A letter designating the cigarette lot (A, B, C or D) was printed on each packet and each carton. All cartons from the same lot were placed in a box wrapped in an air-tight polyethylene bag and stored in a refrigerator at approximately 40° F. The cigarettes

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were kept fresh and at the desired moisture content, 13% ± .5%, throughout the experiment. Moisture content is a critical factor affecting the smoking characteristics of cigarettes. It is believed that 1% difference in moisture content could bring about 10% change in the "taste" of the cigarette smoke (1).

5.2.3 Cigarette Handling, Coding and Serving

One carton of each lot of cigarettes was taken out of the refrigerator one day before the actual smoking tests, and the packets were kept in desiccators to equalize and adjust the cigarettes to room temperature. The proper quantity of cigarettes for a smoking test were placed in labeled jars on the cigarette rack (Figure 5.1). Cigarettes not used in smoking tests within 24 hours were destroyed and replaced with fresh cigarettes. Extreme care was exercised in storing and handling the test cigarettes, e.g. hands were clean and odor-free; every individual cigarette was handled gently to avoid bad ends.

In all smoking tests, cigarettes were labeled (by hand) with codes each consisting of a random three-digit number, excluding zeros or repeated digits within one code. Codes were used as a physical method to avoid psychological errors or response-bias introduced by alphabetical letters or single-digit numbers.

Cigarettes representing a given triangle were placed in the proper order on a particularly selected ashtray. The

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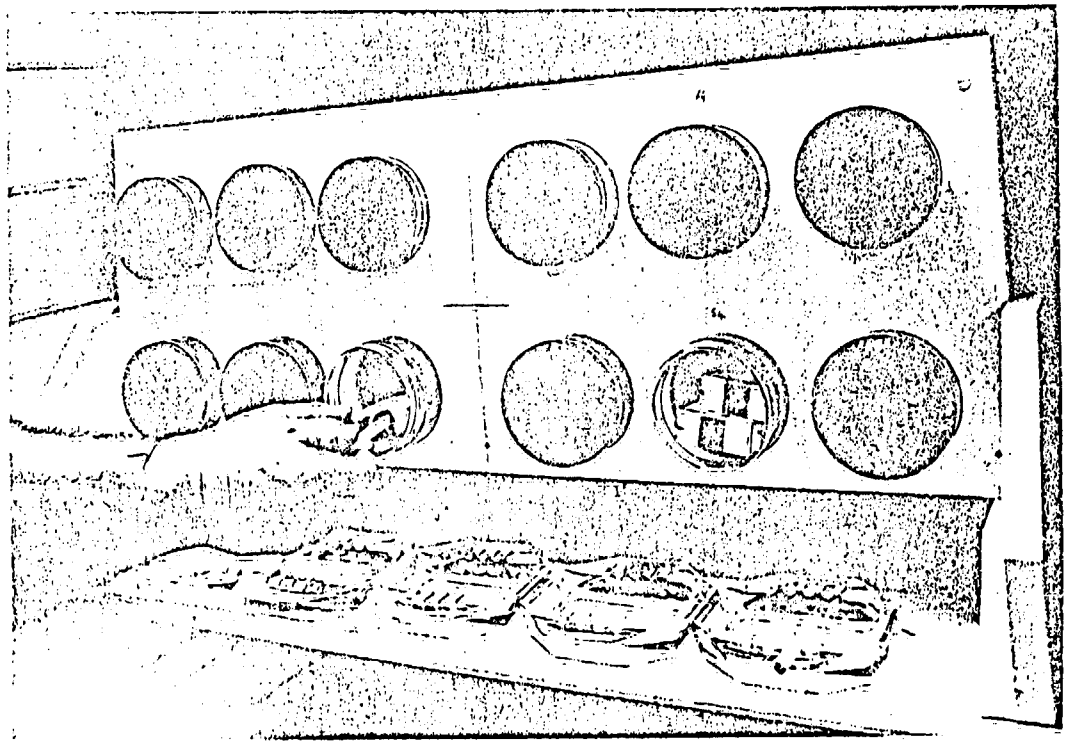

Figure 5.1 A convenience rack for proper storage and handling of cigarettes prior to coding and serving to the panelists

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ashtray, the instruction sheet, and the response card were placed in the booth (Figure 5.2) when the subject presented himself for a smoking test. All smoking tests were taken in the booths under temperature-humidity regulated atmosphere, approximately 70° F and 60% relative humidity.

5.2.4 Smoking Technique

The method of smoking constitutes one of the most critical variables to be "standardized" as much as possible. Although the inherent variability among people in their method of smoking cannot be completely eliminated, there are ways and techniques to minimize such variability. For example, large puffs drawn rapidly would presumably produce results in terms of smoke flavor different than small puffs drawn slowly.

Cigarette marking (Figure 5.3) was designed as a physical method to control both the amount and the "quality" of the stimulus (smoke). Extensive studies (77, 86, 87) indicate that the constituents of mainstream cigarette smoke vary from puff to puff and the variability is markedly large during the last several puffs after the cone has passed through the remaining butt (1/3 of the cigarette length). The smoking characteristics would presumably vary minimally between the two marks (5 mm and 40 mm from the ignition tip).

Another critical variable is the method by which the cigarette is lighted, whether by match, benzine lighter, butane lighter, or electric lighter. Undoubtedly, a match

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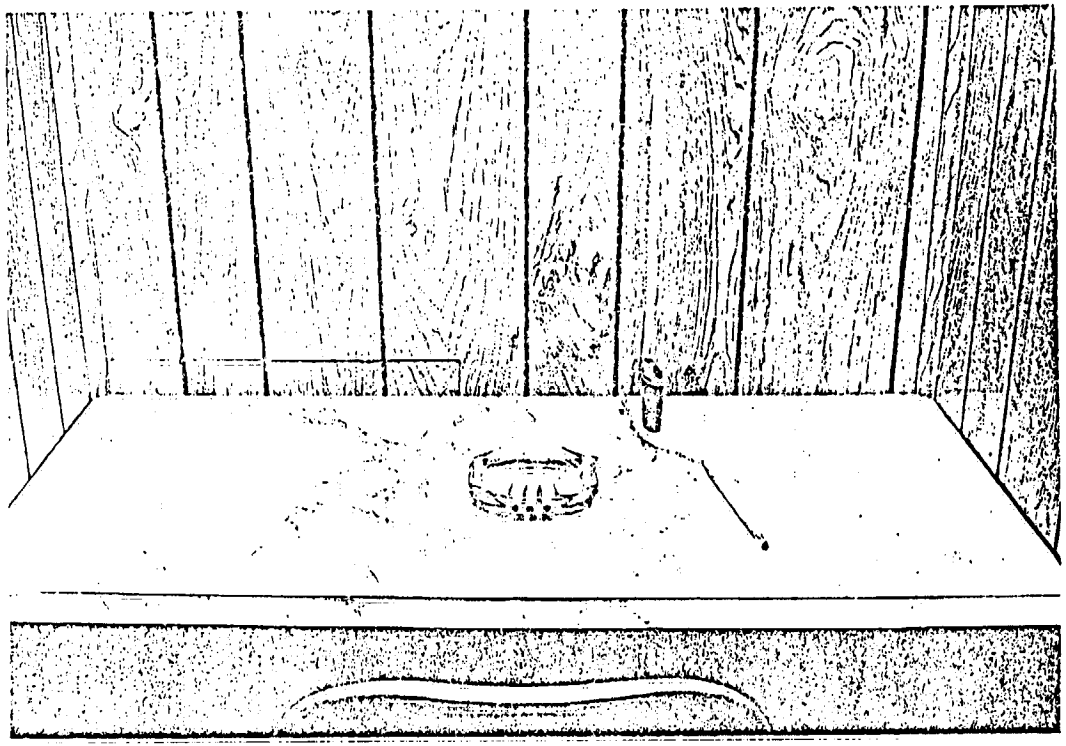

Figure 5.2 Booth prepared for a triangle smoking test. The test cigarettes are arranged on the ashtray; the butane lighter, the instruction sheet and the response card are clearly visible

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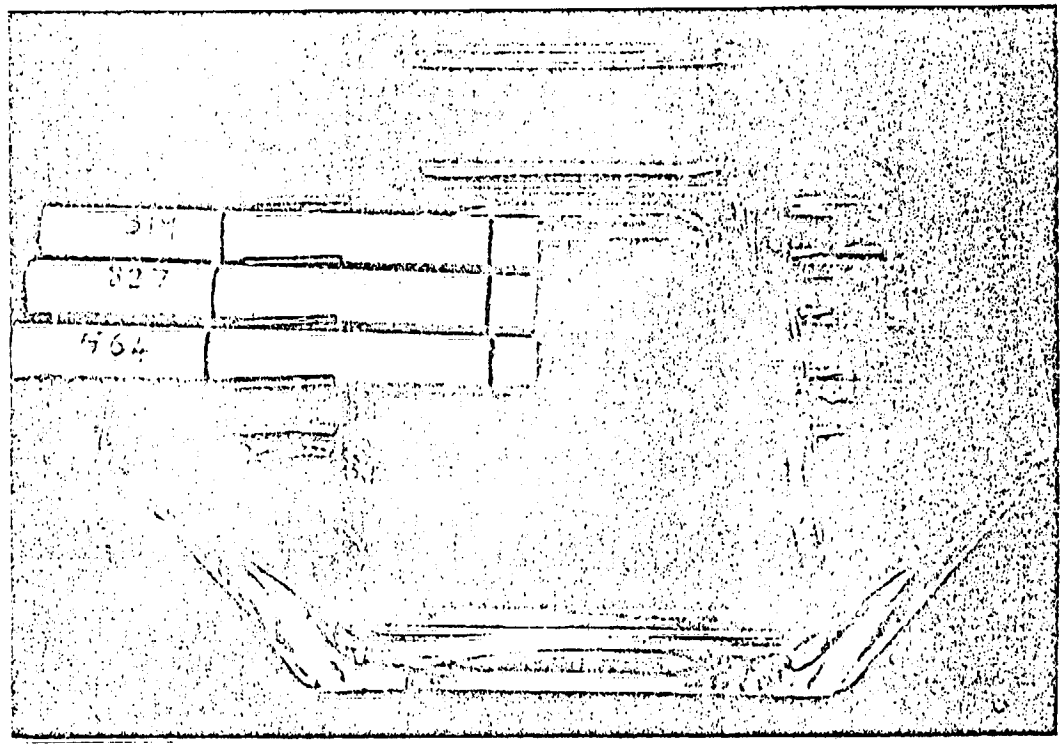

Figure 5.3 Three coded cigarettes presented on the ashtray (in a specific order) for a triangle smoking test. The two marks on each cigarette are used to control the amount of stimulus (smoke)

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or a benzine lighter introduces "odor" (uncontrolled variable) mostly recognized during the first few puffs. To control this variable, a butane lighter was provided in the booth for lighting the test cigarettes. Since butane burns nearly completely, it presumably should not introduce odor of its own to the smoke.

The subjects were provided with explicit instructions (Appendix Figure 13) on the smoking technique to be employed during the test. Only after having carefully read and understood the instructions was a subject allowed to proceed deliberately with the test (Figure 5.4). The instructions were: (a) to follow the order of presentation, from left to right, (b) to light the three cigarettes, one at a time, from the correct end, (c) to start testing as and when the burning zone reaches the first mark, (d) to limit the number of puffs to three to four with no inhalation, and (e) to finish the test before the burning zone reaches the second mark. The subject was asked to circle the number on the response card (Appendix Figure 14) corresponding to that of the odd cigarette.

5.2.5 Design of Smoking Comparisons

The smoking comparisons were designed to provide three types of detectable differences that can be used in panel selection and training:

A vs. B effect of blending,

B vs. C effect of casing,

and C vs. D effect of flavoring materials.

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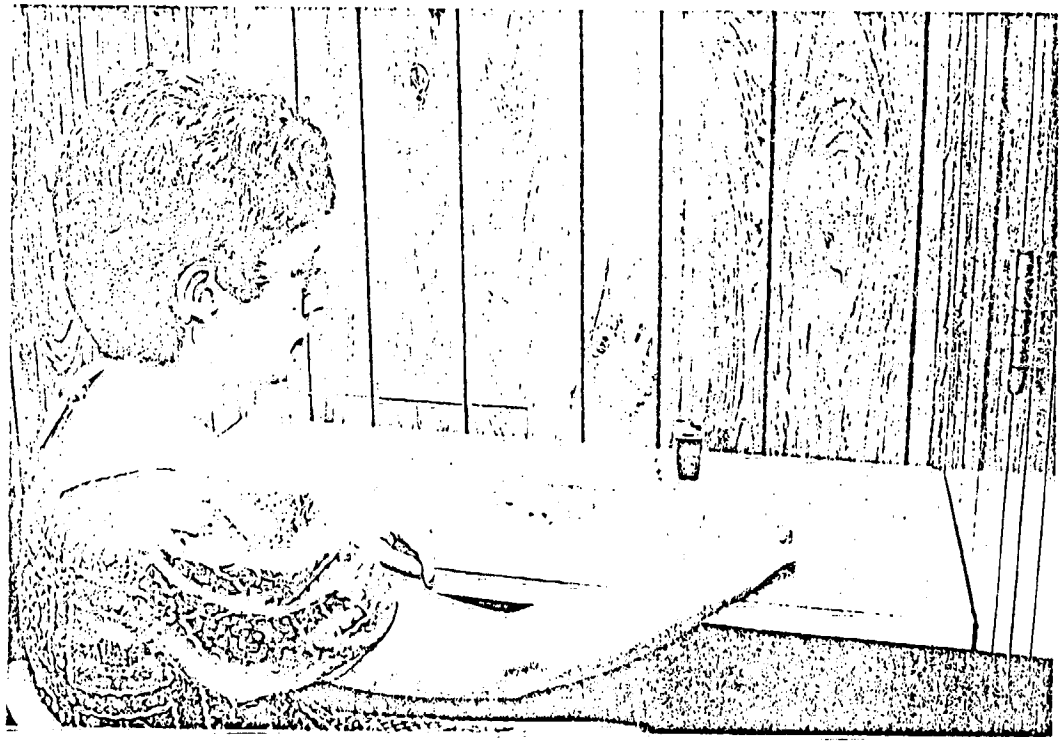

Figure 5.4 A panelist taking a triangle smoking test in the booth to minimize the influence of extraneous (non-stimulus) variables on the subject's response

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The null hypothesis supposed that there was no detectable difference in each of the three smoking comparisons against the alternative hypothesis that there was a difference of decreasing order, that is, A-B > B-C > C-D. Hence, smoking tests were given to the subjects in the order of decreasing intensity of the difference or increasing difficulty in detection. In other words, the smoking tests were designed not only to qualify subjects as panelists but also to train the subjects on how to detect differences.

Most studies on panel selection (6, 20, 21, 23) recommend using simple tests with samples obviously "different" first, but later the tests should be of increasing difficulty. The panelists are then selected or ranked on the basis of percentage of correct answers with all panelists taking the same number of tests the same number of times at each level of difference. As the subject proceeds from one comparison to another, he would presumably be better trained as well as more familiar with the nature of the test, hence, more able to detect smaller differences.

Each subject took each of the smoking comparisons in five "replications" or triangles, one at a time, as follows:

Order	Comparison	Sequence of Test				
		1	2	3	4	5
1st	A vs. B	AAB	ABA	BAA	BBA	BAB
2nd	B vs. C	BBC	BCB	CBB	CCB	CBC
3rd	C vs. D	CCD	CDC	DCC	DDC	DCD

For a subject to be considered as a potential panelist, he had to take all the above smoking tests (15 triangles), one

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at a time, in the above order. A subject's response in each triangle was marked as "hit" (given the value 1) if he correctly identified the odd cigarette or "miss" (given a zero) if he was unable to identify the odd.

In each comparison the possible number of triangles is six. It was decided to run only five triangles because the improvement in the results (in terms of α[4] and β[4] errors) by including the sixth triangle does not justify the required amount of time and material. In addition, the comparisons were not to be dealt with separately (in panel selection) but rather collectively as a series of 15 triangles.

5.3 Results and Discussion

5.3.1 Panel Selection

The selection technique was based on the fact that all subjects who participated in the smoking tests took three smoking comparisons replicated five times. A subject who completed all 15 triangles was selected as a panelist if he showed an ability to detect the differences in the three comparisons beyond the chance probability. Since the chance probability of correct identification in one triangle is 33.3% and the alternative hypothesis is one-tailed, at least 9 correct identifications (in 15 triangles) are required for significance at the 5% level (18). A subject was only

[4] α error is the probability of selecting a panelist who does not have a discriminating ability, whereas β error is the probability of rejecting a panelist who does have a discriminating ability.

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selected as a panelist if his total number of correct identifications of the odd cigarette in all 15 smoking tests (total score) was 9 or more.

As mentioned earlier, the desired panel size was 15-20 panelists, however, to be sure that this number of panelists will be available to take a series of smoking tests within a reasonable period of time, the decision was made that at least 30 panelists should be selected. Smoking tests continued with subjects from among the original 93 volunteers (candidates). When a subject finished all 15 triangles, his total score was calculated, and a decision made whether to qualify the candidate as a panelist or not. When the total number of subjects qualified as panelists reached 30 individuals, the process of panel selection was considered completed. From the roster of 93 volunteers, those who completed the required 15 triangles were 36 subjects from among whom only 30 were selected as panelists. Table 5.3 shows the mean of total score for all 36 subjects as well as for the 30 panelists. It is well to indicate that those who were not selected as well as those who did not take all 15 triangles by the time the selection process was completed can still be considered as candidates for some future panel. The problem of non-availability and/or discontinuation of panelists necessitates that panel selection may be considered as an on-going process.

It had been hypothesized that there was a detectable difference in each of the smoking comparisons (A-B, B-C and

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Table 5.3 Subjects' mean and range of total scores[a] in all smoking tests for panel selection and training (15 triangles)

# of subjects	Mean	Min	Max	SD
All 36 subjects	9.81	8	14	1.833
Panelists (30)	10.30	9[b]	14	1.557

[a]A "score" is the number of correct identifications in one comparison with five triangles, hence, total score is the total of correct identifications in the three comparisons (15 triangles)

[b]In 15 triangles, number of correct identifications required for significance at 5% level is 9. Chance probability is 33.3% and the hypothesis is one-tailed

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C-D) and that these differences were supposedly of decreasing intensity. Although there was no physical method to actually measure the difference in each smoking comparison, a subject's response to the difference in terms of number of correct identifications of the odd (score) reflects to a certain extent the magnitude of that difference. Table 5.4 shows that the differences among the subject's mean scores in the three smoking comparisons were significant. Table 5.4 also shows that the mean score was significantly greater in the A-B comparison than the B-C and C-D and suggests that the detectable difference in these comparisons was in the order of A-B > B-C > C-D. The fact that the mean score decreased in successive tests even though the subjects were presumably gaining familiarity with the test suggests that the comparisons were in fact more difficult and supports the principle of training while selecting -- starting with the larger difference and ending with the smaller difference.

5.3.2 Statistical Analysis of Panel Results

Although there was no restriction on the selection of candidates from among the volunteers with respect to smoking habit, it was decided to conduct some comparative studies on the smoking habits of the 36 subjects who completed all 15 tests versus the 30 panelists who were selected. Pertinent statistics about the subjects were elicited by a questionnaire (Appendix Table 7). The 30 selected panelists included 90% of the cigarette smokers among the 36 subjects who completed the

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Table 5.4 Subjects' mean scores[a] in each of the smoking comparisons for panel selection and training

Comparison	Mean score	
	All subjects (36)	Selected panelists (30)
A-B	3.50	3.67
B-C	3.22	3.40
C-D	3.08	3.23
$LSD_{.05}$	.18	.20
C.V.	21%	20%

[a]A mean score is the average of the subjects' scores in each smoking comparison

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tests, 80% of the pipe or cigar smokers, and 70% of the non-smokers (Table 5.5). Hence, it can be said that in selecting panelists for use in sensory testing of cigarette smoke, cigarette smokers would be more likely to demonstrate discriminating ability than non-cigarette smokers. Table 5.5 also indicates that within the group of cigarette smokers those who smoke 5-20 cigarettes/day are more likely to become panelists than those who smoke 20-30 or 30-40. It is well to emphasize that the number of subjects in each class is not large enough to draw a completely conclusive judgment.

The fact that the different groups of subjects had different abilities to detect the differences in the three smoking comparisons initiated the idea of introducing the factor of smoking "intensity" (abbr. SMKINT = number of cigarettes smoked per day x number of years the subject has been smoking divided by 100). From the physical point of view, this factor is actually measuring experience rather than intensity. The term "intensity" was used to demonstrate the inclusion of time (years) and indirectly to reflect the subject's age. Studies on subjects' sensitivity as related to their smoking habit emphasized the importance of both the quantity being smoked and age (59).

The actual values of smoking intensity for cigarette smokers (Appendix Table 7) were stratified into five classes, 1 through 5. Non-smokers were assigned the value zero and pipe and cigar smokers were tentatively classed at 6 (Table 5.6).

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Table 5.5 Classification of panelists according to their smoking habits

Group	# of Panelists	% Selected[a]
Non-smokers	5	71
Pipe and cigar	8	80
Cigarettes	17	90
# Cigarettes/day		
5 to < 20	6	100
20 to < 30	5	83
30 to < 40	4	80
40 or more	2	100

[a]Percentage of the number of subjects qualified as panelists to the total number of subjects who completed the required smoking tests (15 triangles)

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Table 5.6 Stratification of the subjects' smoking intensity values {SMKINT = (years of smoking x cigarettes smoked/day)/100}

SMKINT stratum	Description
0	Non-smokers
1	SMKINT > 0 to < 1.5
2	= 1.5 to < 3
3	= 3 to < 6
4	= 6 to < 9
5	= 9 or more
6[a]	Pipe and cigar smokers

[a]Temporary assignment of class value to be replaced by a scaled score based on average performance of pipe and cigar smokers

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Regression studies were carried out between the subjects' discriminating abilities (scores) and their SMKINT classes. The differences due to SMKINT were highly significant, but a statistical problem arose because the class value for pipe and cigar smokers was not properly scaled (X'X matrix was not of full rank and the regression line could not be established). Hence, adjustments had to be made to class 6 to be able to use smoking intensity as one continuous variable, namely "SMKINT-C". A SMKINT value had to be reassigned to the pipe and cigar smokers by employing the following technique: A diagram showing mean scores by all 36 subjects on the y-axis and SMKINT values 0 through 5 on the x-axis was fitted statistically. Mean scores were plotted for different SMKINT values (Table 5.7) and a line was drawn through the points (Appendix Figure 15). Where the line crosses the 3.23 value (mean score for the pipe and cigar smokers) on the y-axis, a straight line to the x-axis was then drawn.

The new SMKINT-C value for pipe and cigar smokers as determined by this graphic procedure is 1.4. The same technique was used for the selected panelists and the re-assigned SMKINT-C value for pipe and cigar smokers was 3.4 (Appendix Figure 16).

A regression study for the relationship between the subjects' discriminating abilities in terms of mean scores and their smoking intensities in terms of values of SMKINT-C was performed (Appendix Table 8). There was a significant positive relation with almost the same regression coefficient

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Table 5.7 Mean smoking scores by all subjects and selected panelists ranked according to SMKINT-C[a]

SMKINT-C	All subjects[b]			Selected panelists[c]		
	Tests	Subject	Mean score	Tests	Panelist	Mean score
0	21	7	3.09	15	5	3.26
1	9	3	3.22	9	3	3.22
2	21	7	3.29	18	6	3.38
3	9	3	3.33	9	3	3.33
4	9	3	3.22	6	2	3.67
5	9	3	3.78	9	3	3.78
1.4[d]	30	10	3.23			
3.4[d]				24	8	3.50

[a]To be able to consider SMKINT as one continuous variable "SMKINT-C" new values were reassigned to the pipe and cigar smokers by employing their average score

[b]Those who completed the required smoking tests (15 triangles)

[c]Those who were selected as panelists (score of 9 or more)

[d]New values of smoking intensity for pipe and cigar smokers among all subjects (1.4) and selected panelists (3.4)

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for all subjects and for selected panelists. A summary of the values of mean scores and SMKINT-C as well as their regression coefficient is given in Table 5.8. This relationship was further demonstrated by plotting the regression line for all subjects (Figure 5.5) and selected panelists (Figure 5.6). In comparing the two figures with one another, the same relationship exists, however, the regression line for panelists (with 3.19 intercept) is higher (more discriminating ability) than that for all subjects.

These results indicate that if one starts with a heterogeneous group of people (non-smokers, cigarette, pipe, cigar smokers, of different ages) and selects from among them panelists for cigarette smoke evaluation, it is most probable that cigarette smokers will have a relatively greater chance to be selected.

It is not true that a certain group of individuals cannot be panel members. Through the process of selection and training, individuals from diversified groups can be selected, but the probability of selection of a certain number of panelists within each group (within the appropriate amount of time and material) will vary.

Although the mean score for cigarette smokers (among all subjects) is greater than that for pipe and cigar smokers, which in turn is greater than that of non-smokers (Table 5.9), some individual pipe and cigar smokers showed more discriminating ability (higher score) than some individual cigarette smokers. Furthermore, a few individual

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Table 5.8 Regression of mean scores of all subjects and panelists with relation to their smoking intensity, SMKINT-C

SMKINT-C	All subjects[a]	SMKINT-C	Selected panelists[b]
0	3.09	0	3.26
1	3.22	1	3.22
1.4	3.23	2	3.38
2	3.29	3	3.33
3	3.33	3.4	3.50
4	3.22	4	3.67
5	3.78	5	3.78
$LSD_{.05}$	.178		.198
C.V.	20.5 %		19.5 %
Intercept	3.09 ± .105		3.19 ± .134
b	.096 ± .045		.097 ± .046

[a]Those who completed all required smoking tests (15 triangles)

[b]Those who correctly identified the odd in 9 or more triangles, hence, qualified as panelists

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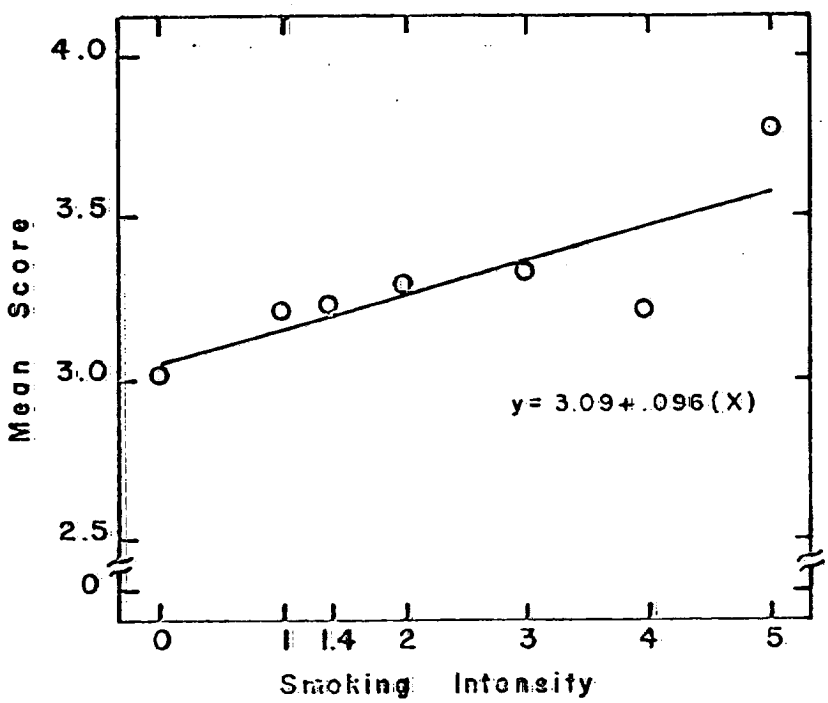

Figure 5.5 The relationship between mean scores of 36 subjects and their smoking intensities, SMKINT-C

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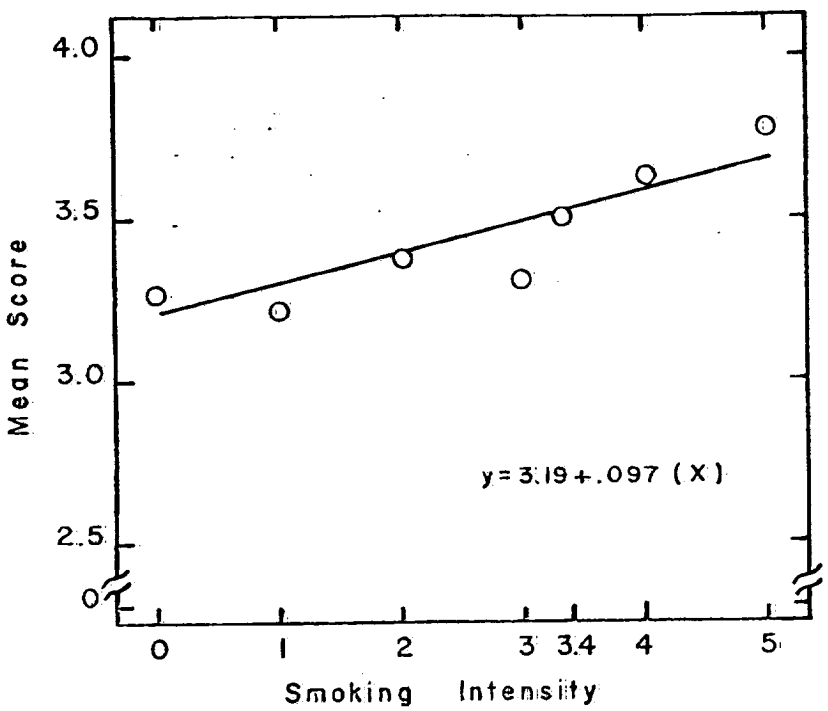

Figure 5.6 The relationship between mean scores of the 30 selected panelists and their smoking intensities, SMKINT-C

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non-smokers had higher scores than some pipe, cigar and cigarette smokers.

The nature of the smoking tests employed in selecting the panel determines the type of activities to be assigned to that panel, and vice versa. A correlation study and a Chi-square-test study covering the subjects' (as well as the panelists') discriminating ability in the three smoking comparisons, A-B, B-C and C-D, were carried out. The results, shown in Table 5.10, show that the subjects' ability to detect the difference in the C-D comparison is significantly correlated with their ability to detect the differences in B-C and A-B. In other words, a subject who is able to detect the difference in the C-D comparison is also able to detect the differences in both B-C and A-B comparisons.

It is evident from the data (Appendix Table 9) that those subjects who did not have a score of 9 (therefore, were not selected) had lower scores in the C-D comparison than those who were selected. This may indicate that the C-D comparison (with less intensity of difference -- more difficult) can be used in panel selection. If the experimenter does not have the time and material to run the three comparisons (each with five triangles), he can run one C-D comparison with five triangles and select those who get scores of 4 or more. However, this procedure is not desirable because it ignores the value of training. Employing smoking comparisons with presumably large differences will help familiarize the subject with the nature of the test and

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Table 5.9 Mean smoking scores for different groups among all subjects and selected panelists

Group	All subjects	Selected panelists
Cigarette smokers	3.37	3.48
Pipe, cigar smokers	3.23	3.50
Non-smokers	3.09	3.26
$LSD_{.05}$	.18	.20
C.V.	20.5 %	19.5 %

Table 5.10 Correlation and Chi-square studies between the subjects' smoking scores in the three smoking comparisons

Comparison	Correlation study			Chi-square tests		
	A-B	B-C	C-D	A-B	B-C	C-D
A-B	--	NS	.39**	--	NS	19*
B-C	--	--	.34*	--	--	16*
C-D	--	--	--	--	--	--

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train them on how to detect minor differences in the subsequent tests. The nature of the differences in smoking characteristics that will be facing this particular panel during the actual evaluation of the experimental tobaccos may be not only due to added flavorings but also due to changes in the sugar and nicotine levels best characterized by the differences associated with blending and casing. This conjecture is supported by the commonly accepted hypothesis that the main characteristics possessed by a blended cigarette are the additive effects of blending, casing and flavoring.

The data in this study reveal that the pattern of the scores in the smoking comparisons is variable due to the variability or rather selectivity among individuals in their scores. Selecting and training the subjects on the basis of the three types of differences will bring about a panel with greater discriminating ability than a panel trained on only one type of difference.

5.3.3 Effect of the "Odd" Position

Each of the three smoking comparisons was given in five triangles and the subjects were always asked to follow the order of presentation. In fact, these triangles do not constitute real replications of the same test because each triangle has its own specific arrangement of the sample-cigarettes presented. The question arises whether the subjects respond similarly to the different triangles; that

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is, whether certain arrangements favor a higher score (ability to correctly identify the odd) than others.

In a recent investigation (33), triangle tests were used to study the taste quality of milk with "a" or without "b" additives. In comparing the responses of the subjects towards different triangles, e.g. "aab", "aba", "baa", "bba", "bab" and "abb", there were no significant differences. Some subjects were consistently more sensitive to those triangles comprising two b's and one "a" than to those comprising two a's and one "b". Few subjects were noticeably resistant to or against the sequence "bab". The results of this experiment on milk show that neither the position nor the kind of the odd had any effect on the subject's responses.

During tabulation of the subject's scores in the smoking tests, a difference due to "position" of the odd was observed and, hence, examined statistically.

By assigning the letter F for the first cigarettes in the comparison (A-, B-, C-) and the letter S for the second cigarettes (-B, -C, -D), Table 5.11 can be constructed. It should be observed that the second and fifth arrangements have the odd in the middle but the odd is not the same in both cases.

The possible effect of the position and kind of the odd cigarette on the subject's psychophysical response was investigated using the original results (Appendix Table 10) from all smoking tests for all subjects. A subject's results in each test was expressed either as 1 for correct

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Table 5.11 Subjects'[a] response (score)[b] as affected by the position of the odd in triangle smoking tests for panel selection and training

Smoking comparison	Triangles				
	1 FFS	2 FSF	3 SFF	4 SSF	5 SFS
A-B	28	21	29	28	20
B-C	27	17	27	28	16
C-D	26	14	28	28	16
Total	81	52	84	84	52
Mean[c]	.75	.49	.77	.77	.48
$LSD_{.05}$		.054			
C.V.		68 %			

[a]The 36 subjects who completed the required 15 triangles

[b]Number of correct identifications by all subjects in each triangle in each smoking comparison

[c]Mean score for all 36 subjects in the three comparisons; mean = total/36/3

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identification of the odd or as zero for incorrect identification.

Table 5.11 shows the total scores of all 36 subjects in each triangle for each smoking comparison. It is evident from the results that the subjects respond correctly more often and, hence, their discriminating ability becomes significantly higher when the odd cigarette is not in the middle. There is a highly significant difference between the mean of each of the three arrangements, FFS, SFF and SSF (odd is not in the middle) and each of the two FSF and SFS (odd is in the middle). However, the differences in the means within each group are not significant, implying that it is the position rather than the identity of the odd that is important. The results also showed that there is a possible comparison x position interaction which is not significant. This interaction indicates that the effect of odd position on the subjects' response is different for different smoking comparisons. To investigate this effect more thoroughly the scores of the 36 subjects in each triangle were computed as a proportion to their total scores in the five triangles (Table 5.12). It is clear that as the testing sequence progressed from A-B to B-C to C-D smoking comparison, the subjects' proportion of correct identifications in triangles 2 (FSF) and 5 (SFS) became smaller. This result indicates that as the test comparison becomes more difficult (less differences to detect) the effect of the odd position becomes more prominent.

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Table 5.12 Effect of "odd" position on the proportion[a] of subjects' score in triangle smoking tests for panel selection and training

Smoking comparison	Triangles					Total
	1 FFS	2 FSF	3 SFF	4 SSF	5 SFS	
A-B	22	17	23	22	16	100
B-C	23	15	23	24	15	100
C-D	23	13	25	25	14	100

[a]Proportion (%) of the number of correct identifications of all subjects in a triangle to the total score in the five triangles

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Furthermore, the total scores as well as the proportions of triangles 1, 3 and 4 were combined in one group and those of triangles 2 and 5 in another group (Table 5.13). The chance probability for the distribution of these two groups is 60:40, respectively -- in the absence of any effect due to certain arrangements or certain smoking comparisons. However, the actual findings showed the distribution to be 67:33 in A-B comparison, 71:29 in the B-C and 73:27 in the C-D.

When the same procedure was carried out for the selected 30 panelists, the same conclusions evolved (Appendix Tables 11, 12 and 13); that is, panelists respond correctly more often when the odd is not in the middle. Further, the effect of the position of the odd became more prominent as the difference in the smoking comparison became smaller (more difficult to detect).

The above findings demonstrate the risk involved in applying other workers' sensory findings -- when different subjects and different products were employed. For example, the effect of the "odd" position in a triangle on the subjects' sensory response is not significant in a product like milk but it is highly significant in cigarette smoke.

In panel selection and training it is wise for the experimenter to employ all possible triangles. In using the panel for the evaluation of experimental cigarettes it may be preferable to employ triangles excluding the odd in the middle. This is particularly important if the panel is to be

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Table 5.13 Combined effect of "odd" position (middle versus other) on subjects' response in triangle smoking tests for panel selection and training

Smoking comparison	Totals		Proportions	
	(1, 3, 4)[a]	(2, 5)[b]	(1, 3, 4)	(2, 5)
A-B	85	41	67	33
B-C	82	33	71	29
C-D	82	30	73	27

[a](1, 3, 4) combined scores (or proportions) of all subjects in the three triangles FFS, SFF and SSF

[b](2, 5) combined scores (or proportions) of all subjects in the two triangles FSF and SFS

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used to evaluate experimental cigarettes to determine if a detectable "qualitative" difference exists.

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6. "CALIBRATION" OF THE PANEL PERFORMANCE

6.1 Introduction

Numerous studies (5, 12, 13, 20, 40) have emphasized the value of training a sensory test panel and suggested ways and methods of training. As a general rule, a panel should be at least trained in detecting differences in the major characteristics of the product to be evaluated. This is preferably coupled with the determination of the panel threshold to changes in these major characteristics introduced by the sensory analyst.

Both sugar and nicotine play a major role in developing the smoking characteristics of flue-cured tobacco. A panel selected for use in evaluating experimental tobaccos should at least be familiar with the specific changes that may occur to the smoking characteristics upon the increase (addition) of sugar and nicotine separately. At the same time, the panel may be "calibrated" with respect to their sensitivity to those changes by measuring the panel threshold in terms of just noticeable differenc (JND) -- a quantitative sensitivity to definable increments of difference. The amounts of sugar and nicotine to be added on top of what is already present should not make the total amounts present grossly outside the range of flue-cured tobaccos.

In each series of smoking tests the performance of the panel must be checked by measuring the consistency of each panelist and the homogeneity of the panel as a whole. The

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ideal situation is when all panelists do know what to look for; that is, they are all "uniform" with respect to the nature of the difference in the smoking characteristics.

6.2 Materials and Methods

6.2.1 Design of the Test Cigarettes

The cigarette tobacco was flue-cured from the 1971 crop, variety C-254 from Kinston, analyzing 2.14% nicotine and 15.8% sugar. It was hypothesized that the amount of material to be added should be of two concentrations within +10% of the native level and two above. The desired solutions of inverted sugar and nicotine malate, each at four different levels or concentrations, were prepared (Table 6.1). The four sugar concentrations were made such that when sprayed on the rag tobacco, the added amount would be 5, 10, 20 and 30 mg of sugar per gram of tobacco. The added inverted sugars were made of 50:50 glucose and fructose. Similarly, the nicotine malate concentrations were determined in such a way that when sprayed they would add 1, 2, 3 and 6 mg nicotine per gram of tobacco (the 10% level of nicotine is 2.14 mg/g tobacco). The concentrations of the nicotine malate solutions were determined on nicotine basis, such that when sprayed they added 1.72, 3.44, 5.16 and 10.32 mg nicotine malate per gram of tobacco. The mass conversion of nicotine to nicotine malate is proportional to molecular weights.

The rag tobacco was divided into three equal lots or groups: 0, 1 and 2. Group 0 was used as a standard or

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Table 6.1 Experimental cigarettes used in triangle smoking tests for the determination of panel threshold (JND) for added sugar or nicotine malate

Group	Substance	Label	Additive mg/g	Amount of solute(s)[a] (in grams/lot of 2161 grams at 12% MC)		M.C.[b] %
0	Standard	A	--	--	--	13.09
1	Inverted sugar	11	5	5.4 g dextrose +	5.4 g fructose	13.29
		12	10	10.8	10.8	13.11
		13	20	21.6	21.6	13.07
		14	30	32.4	32.4	13.38
2	Nicotine malate	21	1.72	2.16 g nicotine +	1.79 g malic acid	13.01
		22	3.44	4.32	3.57	12.95
		23	5.16	6.48	5.36	12.81
		24	10.32	12.96	10.72	13.13

[a]This amount was dissolved in 60 ml H_2O and sprayed onto the rag tobacco (2161 g at 12% M.C. predried to 10.5%) to bring the moisture content to 13%

[b]Actual moisture content of tobacco after manufacture

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

control (no additive), whereas each of the remaining two lots was subdivided into four sublots each of 2161 grams. The amount of water sufficient to dissolve the largest amount of the least-soluble additives was 60 ml. Knowing this, each sublot (2161 g) of tobacco was dried down to 10.5% so that the 60 ml water would bring the moisture content back to the proper level of 13%.

For each sublot (2161 g) the required amount of solute was dissolved in 60 ml water and sprayed onto the rag in a "closed" stainless steel rotating cylinder using a mechanical atomizer (in the Department of Products Development of a cooperating company). Necessary precautions were observed in order to secure complete "recovery" and uniform distribution of each additive. Each sublot was packed (immediately after spraying) in an air-tight polyethylene bag. The rag tobacco for "control" cigarettes ("A") was also dried to 10.5% moisture content, sprayed with the exact amount of water necessary to bring it up to 13% moisture content and packed immediately in polyethylene bags.

All lots of tobacco were left overnight to secure complete absorption of the additives as well as equalization of the moisture content before making into cigarettes. Cigarette making, marking and packing were undertaken in the pilot plant of a cooperating tobacco company as per details mentioned earlier. The packets were labeled with numbers designating the lot and sublot, e.g. 11 implies lot No. 1 (sugar), sublot No. 1 (5 mg/g) and so on. The moisture

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content of the cigarettes was determined just before smoking and found to be 13% ± .5% (Table 6.1).

6.2.2 Design of the Smoking Comparisons

The smoking comparisons were designed to determine the panel threshold in terms of just noticeable difference (JND) to added sugar or nicotine malate.

The best known psychophysical method for determining a subject's JND is the dilution method (5, 18, 40). The sensory properties (flavor characteristics) of a product are varied by addition of a standard substance at different levels or concentrations. The JND is determined by comparing each series of concentrations against the standard or control using the method of constant stimuli (5, 62). According to the method of constant stimuli, the test procedure is conducted in steps in a descending (or ascending) order. Each step consists of a triangle test (with replication) in which the subject compares the control against a certain level of additive concentration. It is, psychophysically, advisable to start testing differences between the control and higher level of additives (large difference) and move to a lower degree of differences. This direction will enable the panelist to know what to look for and train him on how to detect minor differences.

The flavor characteristics of a flue-cured tobacco (used as a standard or control "A") were varied by the addition of inverted sugar at four different levels: 30, 20,

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10 and 5 mg per gram of tobacco. Smoking comparisons were designed to determine the panelists' as well as the panel's threshold in terms of just noticeable difference (JND) for the added sugar. The smoking comparisons were conducted in steps in a descending order (increasing difficulty) as follows:

1st	standard cigarettes "A" vs.	cigarettes with 30 mg added sugar
2nd	"A" vs.	20
3rd	"A" vs.	10
4th	"A" vs.	5

Each step consisted of five triangles comparing the standard "A" with the sugar-treated "t" in the following order: ttA, tAt, Att, AAt, then AtA.

The cigarette handling, coding and serving, as well as the smoking technique, were all the same as those described earlier.

Only qualified panelists were requested to take these smoking tests and all tests were conducted in the booths. Each panelist had to complete all the 20 smoking tests in order to consider his results. It was decided that a panel of 20 members would be sufficient to obtain conclusive judgments.

Smoking comparisons for determining nicotine malate JND were then conducted in the same manner employed in sugar JND. It was concluded from most studies (5, 17, 18) that the number of trained panelists employed in a single series of tests should be 15-20, according to the degree of training.

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6.3 Results and Discussion

6.3.1 Panel Threshold (JND) for Sugar

Since the degree of training the panelists achieved was not known yet, it was decided to employ 20 panelists, the maximum number postulated as required for rendering conclusive judgments. Hence, smoking tests were to continue until at least 20 panelists completed the necessary 20 tests; actually 21 panelists completed these tests and were used in this study.

In each smoking comparison the panelist's ability to identify correctly the odd cigarette in the five triangle tests (beyond the chance probability) reflects his response towards the difference in flavor characteristics due to the addition of sugar at a particular level.

Each panelist's proportion of correct identifications of the odd cigarette (in five triangles) and the average proportion for all 21 panelists were computed in each smoking comparison (Table 6.2). A regression study was performed for panelist's proportions on added sugar concentrations (in mg/g tobacco). The analysis of variance (Table 6.3) shows that the regression is highly significant. Average proportions for the four stimulus values (in the four smoking comparisons) were plotted. The regression line (Figure 6.1) was drawn using the values of regression coefficient and intercept in Table 6.3. The linearity was further checked by computing the F-value for the sum of squares of deviations from regression which was found not significant.

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Table 6.2 Panelists' proportions of correct identification of the odd in triangle smoking tests for sugar threshold (JND) determination

Panelist	Added sugar, mg/g			
	5	10	20	30
AWA	.4	.6	.6	.6
SWB	.6	.6	.6	.8
HCC	.8	.8	.8	1.0
GD	.2	.6	.8	.8
MME	.2	.4	.8	.8
RG	.4	.6	.6	.8
HRH	.2	.4	.6	.6
SNH	.4	.6	.6	.8
BH	.2	.8	.8	.8
BK	.6	.6	.6	.8
RCL	.4	.6	.6	1.0
TJM	.4	.6	.6	.8
DFM	1.0	.6	.6	.8
DP	.4	.4	.6	.8
RP	.4	.6	.6	.8
HMS	1.0	.6	.6	.8
RS	.4	.6	.6	.8
JW	.6	.6	.6	.8
WWW	.4	.6	.6	.8
JAW	.6	.8	.8	.8
WGW	.8	.4	.6	.6
Panel mean	.50	.58	.65	.79

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Table 6.3 Analysis of variance -- regression of panelists' proportions of correct identification of the odd on levels of added sugar (using 21 panelists)

Source	d.f.	SS	MS	F
Sugar	1	.9551		47.566**
Panelists	20	.6114	.0306	1.523
Error	62	1.2449	.0201	
Total	83	2.8114		

Intercept = .4481 ± .0304 C.V. = 22.5%

b = .0111 ± .0016 SD = .1417

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

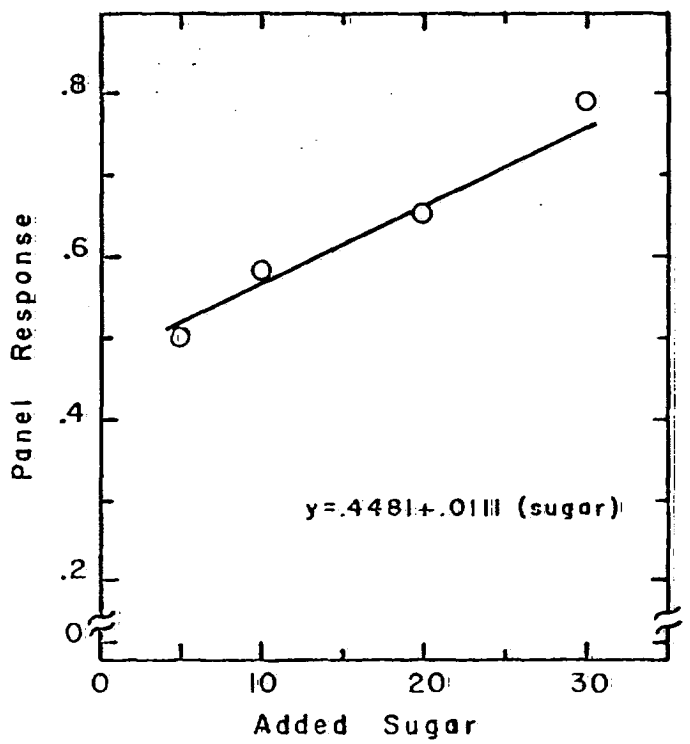

Figure 6.1 The relationship between panel response (mean proportions of 21 panelists) and added amounts of sugar (mg/g)

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

The linear regression of proportion (panel response) on the actual sugar levels brought about a psychophysical problem. The intercept value was significantly higher than the chance probability (.4481 vs. .3333) which indicates that the subject can significantly detect a difference when there is no difference. This suggested that the empirical description did not conform to the existing psychophysical theory.

Weber's law of psychophysics (25) states that it is not the arithmetic difference which a subject perceives but the ratio of the difference to the standard stimulus. Tests of differential sensitivity have always been related to Weber's law which was originally written

$$\frac{\Delta S}{S} = k \quad \text{or} \quad \Delta S = kS$$

where ΔS is a detectable increment in response to S which is the value of standard stimulus corresponding to a defined unitary change in response, and k is a constant called Weber's fraction.

A further study (62) indicated that k tends to be constant for moderate values of S, but k usually increases greatly when S is decreased and detection becomes a problem for the subject. Thus, Weber's law has been modified to

$$\Delta S = k(S + a)$$

where "a" is a small value on the stimulus dimension defined as the minimal amount that can be considered as different

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from the effect of extraneous non-stimulus variables or "noise". In fact, "a" is the absolute threshold (AL) in the classical theory.

Most studies on psychophysics (5, 25, 62) indicate that the S-R relationship is better described by Fechner's law. Fechner regarded the constant $\Delta S/S$ as a minute sensory unit which is defined as

$$\frac{\Delta S}{S} = k\Delta R$$

where ΔS and ΔR were suggested to be true limiting values, dS and dR, hence by integration

$$R = a \ln(S) + b$$

where R is the response, "a" is the constant defined earlier and b is an integration constant. Fechner's law states that something in response (psychological continuum) that may be called its quantity, R, is proportional to the natural logarithm of the stimulus (physical continuum), S. Fechner's law (also called Weber-Fechner's law) was derived mathematically from Weber's law, but each explains different psychophysical phenomena. Fechner's law can be used over a wide range of stimulus dimension, whereas Weber's can be used only for moderate values in the stimulus dimension.

Consequently, the linear regression of panel response to ln (sugar) levels was computed (Table 6.4). Interestingly, the fit in the case of linear regression of proportions on actual sugar levels tended to be slightly better than the fit on ln (sugar) levels, but the difference was not significant.

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Table 6.4 Analysis of variance -- regression of panelists' proportions of correct identifications of the odd on ln (sugar) levels (using 21 panelists)

Source	d.f.	SS	MS	F
ln (sugar)	1	.9044		43.28**
Panelists	20	.6114	.0306	1.46
Error	62	1.2956	.0209	
Total	83	2.8114		

Intercept = .2370 ± .0616 C.V. = 23%

b = .1519 ± .0231 SD = .1446

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Of most importance is the new value of the intercept, .2370, which is in full agreement with the existing theory of psychophysics. The panel response, in terms of mean proportions of correct identifications of the odd cigarette, was then plotted against the four stimulus values in terms of ln (sugar) as shown in Figure 6.2. The regression line was then drawn using the values of regression coefficient and intercept in Table 6.4.

The homogeneity among the panelists in their responses to the added sugar can be clearly shown by the fact that the F-value for panelists in Table 6.4 is not significant. This may be an indication of the progress of the panelists' training and further may suggest that the panelists knew what to look for relative to the differences in smoking qualities due to the addition of sugar at four different levels.

According to recent developments in psychophysics (5), the just-noticeable-difference (JND) in any stimulus bears a constant ratio to that stimulus. The stimulus must be changed in a certain "fixed" ratio in order to produce equal-interval changes in response. Quantitatively, the JND is the increment in the stimulus that the subject can significantly detect over and above the value of stimulus that can be detected by chance. The stimulus value which a subject can detect by chance in a repeated number of tests is called absolute threshold (AL), which is the value of "a" in Weber-Fechner's law. The difference or detection

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

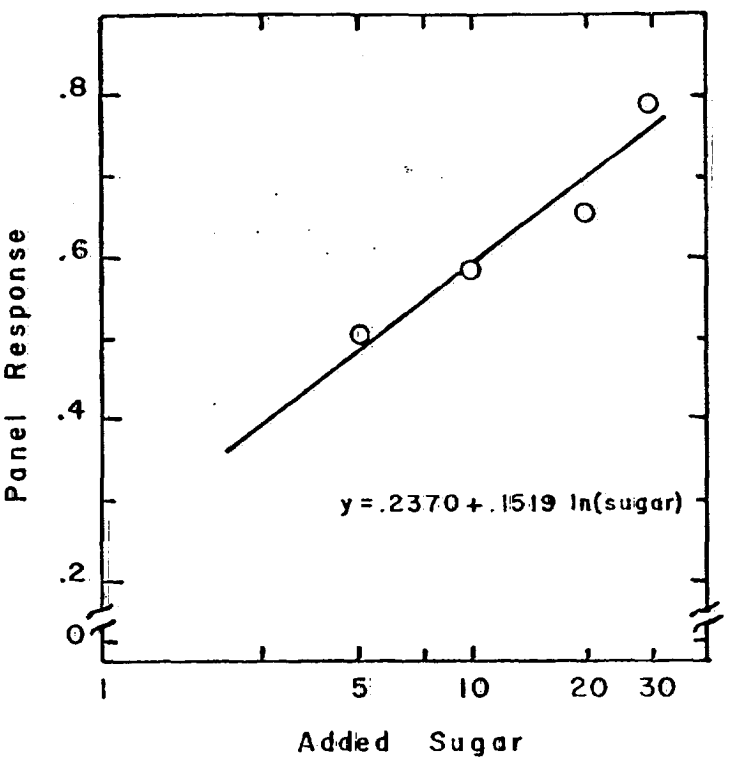

Figure 6.2 The relationship between panel response (mean proportions of 21 panelists) and added sugar (mg/g on a logarithmic scale)

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

threshold (DL) is defined (18) as that stimulus detected in a number of repeated tests beyond the chance probability. The value of stimulus the subject can detect at the 5% level of significance is $DL_{.05}$. A subject's just-noticeable-difference at the 5% level ($JND_{.05}$) is determined by computing the difference between the values of detection threshold ($DL_{.05}$) and absolute threshold (AL).

For smoking comparisons employing triangle tests a method by which the panelist's (as well as the panel's) $JND_{.05}$ can be determined was developed as follows:

(a) A panelist's $DL_{.05}$ is that concentration (level of added sugar) at which the panelist can identify correctly the odd cigarette in a number of triangles at the 5% level. Since the chance probability of correct identification of the odd is .3333 and the standard deviation is .1446 (Table 6.4), a panelist's proportion of correct identifications at the 5% level is

$$P_{.05} = .3333 + 2 \times .1446 = .6225 .$$

Using the values of intercept and regression coefficient, the prediction equation was employed to compute the sugar concentration at which the panelist can get the .6225 proportion of correct identifications, that is

$$.6225 = .2370 + .1519 \ln (\text{sugar}).$$

Solving for ln (sugar) and by anti-log transformation, the required value of $DL_{.05}$ was calculated to be 12.72 mg added sugar per gram of tobacco.

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(b) A panelist's absolute threshold (AL) is that sugar concentration at which the panelist's proportion of correct identification of the odd cigarette in a number of repeated triangles is equal to that of chance alone (.3333). By using the prediction equation

$$.3333 = .2370 + .1519 \ln (\text{sugar}),$$

the panelist's AL was found to be 1.88 mg added sugar per gram of tobacco.

(c) Consequently, a panelist's just-noticeable-difference in sugar addition significant at the 5% level is

$$JND_{.05} = 12.72 - 1.88 = 10.94 \text{ mg/g}.$$

That is, for this panel of 21 trained individuals, the minimum amount of added sugar that can be detected 95% of the time by a single panelist is about 11 mg per gram of tobacco.

The panel's $JND_{.05}$ was determined by employing the same technique. In this case the panel's mean proportion of correct identification significant at the 5% level is

$$P_{.05} = .3333 + 2(.1446/\sqrt{21}) = .3979.$$

The panel $DL_{.05}$ was computed using the same prediction equation,

$$.3979 = .2370 + .1519 \ln (\text{sugar}),$$

and found to be 3.12 mg/g. Using the value of absolute threshold (AL) = 1.88, the panel's $JND_{.05}$ is

$$3.12 - 1.88 = 1.24 \text{ mg/g}.$$

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Both JND values are informative because the panelist's JND is useful in comparing the relative sensitivity from one stimulus substance to another while the panel's JND reflects the expected increase in sensitivity by employing larger panel size.

Also, the JND may be expressed in the form of ratio to pre-existing (native) sugar. With this particular tobacco variety having 15.8% sugar and the panelist's $JND_{.05}$ of 11 mg/g, the relative stimulus magnitude is $\frac{11}{158}$ or about 7%. It is suggested that the $JND_{.05}$ be expressed in both absolute and relative magnitudes.

It should be emphasized that the panelists were actually detecting the differences in smoke-flavor characteristics due to the addition of increasing concentrations of sugar, not to the added sugar per se. One major characteristic of flue-cured tobacco is its relatively high content of sugar as compared to that of Turkish, burley or Maryland tobacco. During pyrolysis (which is initiated in the thermal gradient preceding the burning cone of a cigarette), sugars give acidic substances in the mainstream smoke (77, 78). These substances neutralize some of the alkalinity of nicotine and other related alkaloids in the smoke. The existence of free sugar in the mainstream smoke has been indicated (39).

In this study, the differences in smoke flavor were judged by a panel of 21 trained panelists who were consistent and responded uniformly to the stimulus differences.

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The established value of 7% for $JND_{.05}$ in sugar can presumably be applied to other flue-cured tobaccos of about the same sugar content. This can be of practical importance in measuring crop performance and in blending technology.

6.3.2 Panel Threshold (JND) for Nicotine Malate

The 21 panelists employed in sugar threshold determination were consistent and homogeneous in their responses, therefore, 15 members (from among the panel of 21) were used in the determination of $JND_{.05}$ in nicotine malate. The smoking tests continued until 15 panelists completed the required 20 triangles.

The proportion of correct identifications of the odd cigarette and the average proportion of the 15 panelists for each smoking comparison were computed (Table 6.5).

Regression studies were made for panelists' proportions on natural logarithm of added concentrations of nicotine malate (Table 6.6). The regression was highly significant. The linear model was checked in several ways using proportion or arcsin $\sqrt{\text{proportion}}$ as the dependent variable versus concentration or ln concentration in all combinations. The combination which gave the lowest error variance as well as the lowest coefficient of variation was that between proportions and ln concentrations (levels of added nicotine malate). It is of interest to indicate that the linear regression of panel response (mean

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Table 6.5 Panelists' proportions of correct identifications of the odd in triangle smoking tests for nicotine malate threshold (JND) determination

Panelist	Added nicotine malate, mg/g			
	1.72	3.44	5.16	10.32
AWA	.4	.4	.6	1.0
HCC	.6	.8	.8	.8
GD	.4	.6	.6	.8
MME	.2	.2	.8	.6
RG	.4	.6	1.0	.8
HRH	.2	.4	.4	.6
SHH	.2	.4	.4	.8
BK	.2	.8	.8	.6
RCL	.2	.8	.8	.6
DFM	.6	.6	.6	.6
DP	.4	.2	.4	1.0
HMS	.6	.4	.6	.8
WWW	.6	.6	.6	.6
JAW	.2	.4	.6	.6
WGW	.8	.6	.6	.6
Panel mean	.40	.52	.64	.70

Table 6.6 Analysis of variance -- regression of panelists' proportions of correct identifications of the odd on ln (nicotine malate) levels (using 15 panelists)

Source	d.f.	SS	MS	F
ln-nic. mal.	1	.7951		26.81**
Panelists	14	.5533	.0396	1.33
Error	44	1.3049	.0296	
Total	59	2.6533		

Intercept = .3117 ± .0540 C.V. = 30%

b = .1772 ± .0342 SD = .1722

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

proportions) on actual amounts of nicotine malate was not significant, while it was significant in the case of sugar.

Figure 6.3 shows the above relationship as expressed in a semi-logarithmic scale in which the panel average proportions are regressed against the natural logarithm of added amounts of nicotine malate (NM). A smooth regression line was then drawn using the values of intercept and regression coefficient given in Table 6.6. This figure clearly indicates that the panelists' response (ability to detect difference) to added amounts of nicotine malate can be described by a straight-line relationship when proportion (responses) are regressed against the natural logarithm of the added amounts (stimuli). Again, this is an example in which the stimulus-response relationship obeys Weber-Fechner's law of psychophysics.

The homogeneity among panelists in their response to the added nicotine malate is indicated by the fact that the F-value for panelists is not significant (Table 6.6). The consistency of the panelists suggests the progress of their training and presumably reflects their understanding of the differences in smoking characteristics due to the addition of nicotine malate.

A panelist's $JND_{.05}$ was determined by employing the method described earlier. First, the panelist's proportion of correct identifications of the odd cigarette at the 5% level ($P_{.05}$) was computed using the value of standard deviation, .1722 (Table 6.6), hence

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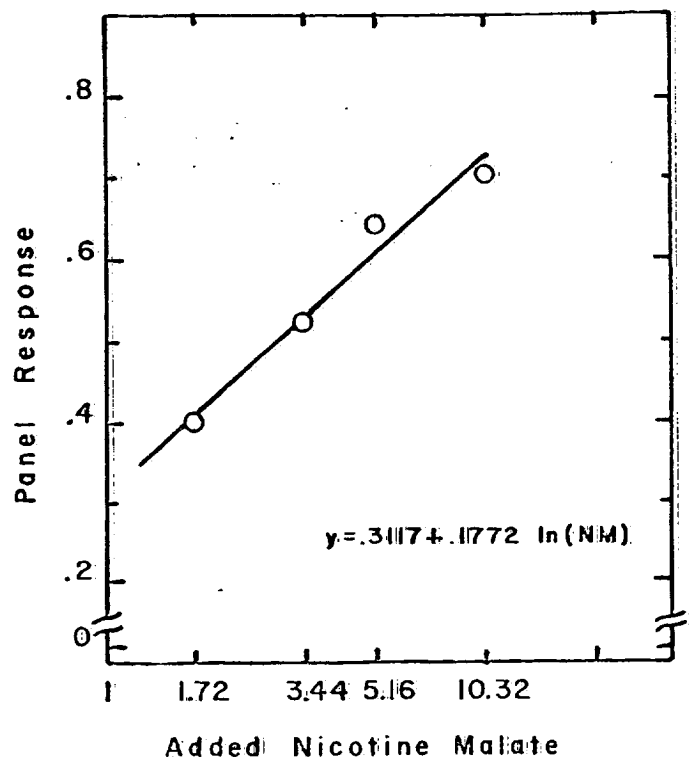

Figure 6.3 The relationship between panel response (mean proportions of 15 panelists) and added nicotine malate (mg/g on a logarithmic scale)

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

$$P_{.05} = .3333 + 2 \times .1722 = .6777 .$$

Substituting in the prediction equation,

$$.6777 = .3117 + .1772 \ln (NM)$$

and solving for ln (NM), the panelist's $DL_{.05}$ = 7.9 mg nicotine malate per gram of tobacco. Using the chance probability of correct identification in the equation,

$$.3333 = .3117 + .1772 \ln (NM)$$

and solving for the amount of nicotine malate, the required value for absolute threshold AL is 1.13 mg/g.

Hence, the panelist's just-noticeable-difference in added amounts of nicotine malate is

$$JND_{.05} = 7.90 - 1.13 = 6.77 \text{ mg/g} .$$

Similarly, the panel's $JND_{.05}$ was computed and found to be .73 mg/g.

Again, both values of JND are informative. The panelist's JND is of more practical importance since it can be used more efficiently as a measure of sensitivity to a given stimulus substance and in comparing the mean sensitivities to two stimulus substances.

In fact, the actual amount of nicotine malate in the tobacco used is not known, but its nicotine content is 2.14%. This amount reflects both "bound" nicotine (salts) as well as "free" nicotine. If the panelist's $JND_{.05}$ is 6.77 mg nicotine malate, this can presumably be expressed in the form of 3.65 mg nicotine per gram of tobacco. Hence, the relative magnitude (ratio) of the panelist's $JND_{.05}$ for nicotine (using flue-cured tobacco having 2.14% nicotine) is 17%.

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

The above findings, namely that the minimum amount a panelist can detect is 7% of the pre-existing sugar and 17% of the pre-existing nicotine, can be explained in several ways. What the panelist actually perceives is the increment or change in stimulus, 11 mg of sugar per gram of tobacco versus 3.65 mg of nicotine per gram of tobacco, thus the panel is more sensitive in detecting absolute increments of nicotine than of sugar. The stimulus-response (S-R) relationship can be adequately explained by Weber-Fechner's law in both cases. The existing psychophysical theory explains the S-R relationship over a wide range of stimulus dimensions. Weber-Fechner's law works adequately when the stimulus increments are of moderate values and also when the increments get smaller and detection becomes a problem for the panelist.

Since the 15 trained panelists responded more or less uniformly to the stimulus differences, it can be stated with some assurance that the findings can be applied to flue-cured tobacco varieties in general. The just-noticeable-difference (JND) in nicotine malate between two flue-cured tobaccos from the same variety is 6.77 mg/g (or 3.65 mg/g in terms of nicotine) for varieties having around 2% nicotine. These results suggest that smoke panel evaluation can play a major role in identifying the changes in smoke flavor caused by changes in nicotine content.

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

6.3.3 Checking the Panel Performance

As mentioned above, the $JND_{.05}$ in sugar was determined by using a panel of 21 trained panelists, whereas for determining $JND_{.05}$ in nicotine malate a panel of 15 trained panelists was employed.

The 15 individuals comprising the second panel were among the 21 who served in the first panel. The question arises: how did the 15 panelists used in nicotine malate perform in the sugar tests? The proportions of correct identifications in the sugar series for these 15 panelists are listed in Table 6.7. Using the data in this table, regression studies for panelists' proportion of correct identifications (panel response) on ln (amount) of added sugar was made. The regression was also found to be highly significant and, gratifyingly, the data for 15 panelists behaved almost identically as that for the 21 panelists, as shown by the analyses of variance (Tables 6.8 and 6.4, respectively). The average proportions for the four stimulus values for the 15 panelists were plotted (Figure 6.4) and a smooth line was drawn using the values of the intercept and regression coefficient shown in Table 6.8.

There was also a considerable degree of homogeneity among the 15 panelists in their responses to the added sugar -- the F-value for panelists is not significant. But the coefficient of variation and standard deviation were slightly higher for the 15 panelists than for the overall 21 panelists.

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Table 6.7 Panelists' proportions of correct identification of the odd in triangle smoking tests for sugar JND. Results of the 15 panelists who completed the nicotine malate tests

Panelist	Added sugar, mg/gm			
	5	10	20	30
AWA	.4	.6	.6	.6
HCC	.8	.8	.8	1.0
GD	.2	.6	.8	.8
MME	.2	.4	.8	.8
RG	.4	.6	.6	.8
HRH	.2	.4	.6	.6
SNH	.4	.6	.6	.8
BK	.6	.6	.6	.8
RCL	.4	.6	.6	1.0
DFM	1.0	.6	.6	.8
DP	.4	.4	.6	.8
HMS	1.0	.6	.6	.8
WWW	.4	.6	.6	.8
JAW	.6	.8	.8	.8
WGW	.8	.4	.6	.6
Panel mean	.45	.56	.65	.77

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Table 6.8 Analysis of variance -- regression of panelists' proportions on ln (added) sugar for the 15 panelists who completed the nicotine malate tests

Source	d.f.	SS	MS	F
ln (sugar)	1	.5625		23.18**
Panelists	14	.5960	.0426	1.75
Error	44	1.0675	.0242	
Total	59	2.2260		

Intercept = .2647 ± .0785 C.V. = 25%

b = .1418 ± .0294 SD = .1558

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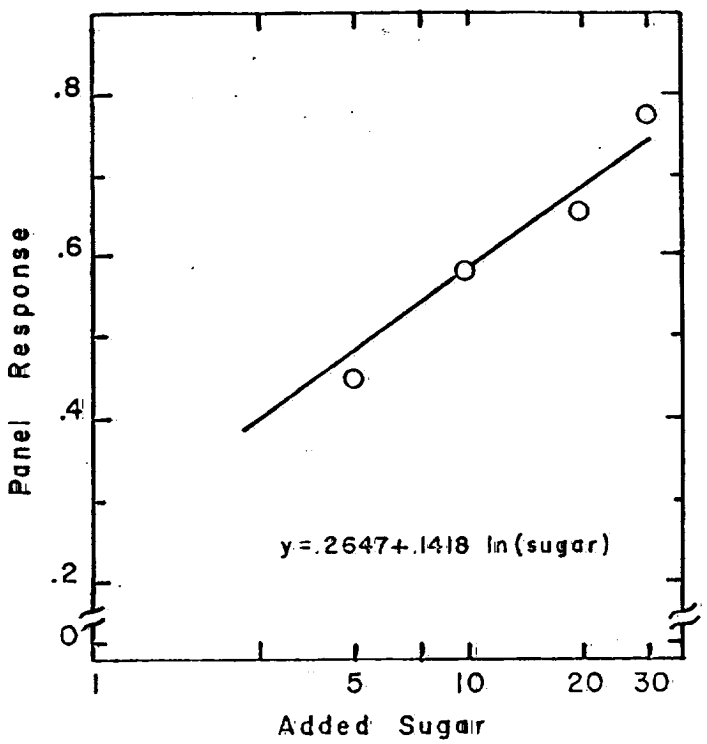

Figure 6.4 The relationship between panel response (mean proportions of 15 panelists) and added sugar (mg/g on a logarithmic scale)

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Using the same technique described earlier, the $JND_{.05}$ for the panelist as well as for the panel were determined to be 12.50 and 1.20, respectively. Upon comparing these values with the values of $JND_{.05}$ obtained by employing 21 panelists (12.50 versus 10.94, and 1.20 versus 1.24), the differences were not significant.

Consequently, the performance of the 15-individual panel is probably as good as that for the 21 as long as the panelists were trained and had reached a proper level of consistency and homogeneity.

The above finding is of great practical importance because of the mere fact that employing a smaller number of panelists means using less material and getting the necessary information within a shorter period of time. As long as the results are obtained with the same degree of accuracy and precision, using a large number of panelists may seem an unnecessary complication.

6.3.4 Effect of the Odd Position

During the determination of the panel JND in added sugar and that in added nicotine malate, each smoking comparison consisted of five triangles, namely ttA, tAt, Att, AAt and AtA. The second and fifth triangles in each comparison had the odd cigarette in the middle position. It was, hence, decided to study the effect of the position of the odd cigarette on the panel response in these smoking tests.

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Table 6.9 shows the panelists' responses in terms of total number of correct identifications of the odd cigarette in the four smoking comparisons for the JND in sugar and those for the JND in nicotine malate. The analysis of data, as confirmed by the LSD-test (Table 6.9) indicates that the panelists' total number of correct identifications of the odd cigarette was significantly smaller in triangles 2 and 5 (where the odd was in the middle position) than in the remaining triangles.

These results agree with those obtained with the A, B, C and D smoking comparisons discussed in section 5.3.3.

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Table 6.9 The effect of position of the odd cigarette on the panelists' response[a] in triangle smoking tests for JND determination

Panelist	Triangles									
	Sugar threshold					Nicotine-malate threshold				
	1	2[b]	3	4	5[b]	1	2[b]	3	4	5[b]
AWA	2	2	4	2	1	3	2	2	3	1
SWB	3	1	3	4	2					
HCC	4	3	4	4	2	4	1	4	4	2
GD	2	2	3	3	2	3	2	3	2	1
MME	3	1	2	3	2	2	1	2	2	2
RG	3	1	3	3	2	3	3	3	3	2
HRH	2	0	2	4	1	2	1	2	2	1
SNH	2	2	3	4	1	1	0	3	3	2
BH	3	2	3	3	2					
BK	4	1	3	3	2	3	2	3	2	2
RCL	3	2	2	3	2	3	1	3	2	2
TJM	3	0	4	3	2					
DFM	3	2	4	4	2	3	1	3	3	2
DP	2	2	2	3	2	3	1	1	3	2
RP	3	2	2	3	2					
HMS	4	1	4	3	3	2	2	4	2	2
RS	3	2	2	4	1					
JW	4	2	3	3	1					
WWW	4	1	3	3	1	3	1	3	3	2
JAW	3	2	4	3	3	3	0	1	3	1
WGW	3	1	3	3	2	4	2	3	2	2
Total	61	32	63	68	38	42	20	41	39	26
Mean	2.96	1.52	3.00	3.24	1.80	2.80	1.32	2.76	2.60	1.72
Mean proportion	.74	.38	.75	.81	.45	.70	.33	.69	.65	.43
$LSD_{.05}$			.11					.12		

[a]Total of correct identifications in the four smoking comparisons in each triangle

[b]Triangles 2 and 5 are having the odd cigarette in the middle, e.g. tAt, AtA

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7. USE OF PANEL AS A RESEARCH TOOL

7.1 Introduction

The principal objective of selection and training a panel is to use the panel in the evaluation of the smoke of experimental tobaccos. The panel was selected and trained on the basis of the panelist's ability to detect differences introduced by the investigator, whereas the panel is used to give the investigator some information about some unknown differences. In the selecting and training of panelists some information can be obtained as to the number of panelists and the number of replications needed to get statistically valid results.

Nicotine occurs in tobacco leaf and presumably in smoke as a "free" alkaloid and also "bound" with organic acids (nicotine salts) in indefinite and variable proportions. Earlier studies (73) reported that most nicotine is bound with organic acids in the cell sap. Nicotine salts of malic, citric, succinic and oxalic acids are insoluble in petroleum ether (PE), whereas nicotine salts of the lower fatty acids, namely acetic and butyric, are soluble in PE and may be considered as free. The ratio of free to bound in the leaf was proposed (65) as an index for the taste quality of the smoke, the greater the quantity of free nicotine the lower the taste quality of the smoke. Unfortunately, there were no data to support that claim and the chemical method used to determine the amount of free and bound nicotine should be

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accepted with caution when compared with today's more advanced analytical procedures. To date there are no valid data comparing the smoking qualities of tobaccos with free versus bound nicotine. Hence, it was decided to employ a panel of 15 trained individuals to gain some information about the detectable "qualitative" difference (if there is any) in smoke flavor between tobaccos with added supra-threshold amounts of free versus bound nicotine.

The experiment was designed to give some additional information with respect to the proper number of replications (triangles) that can be used for statistically valid results. Also, the role of test conditions or environment on the performance (or sensitivity) of the panel was investigated.

7.2 Materials and Methods

7.2.1 The Test Cigarettes

Two lots of flue-cured tobacco variety Coker 254 were sprayed with the same amount of nicotine, but in one lot pure nicotine was sprayed, whereas in the other lot nicotine malate was used. For the smoking comparison to be psycho-physically adequate the level of added nicotine must be above the threshold level that a panel can detect. From the previous experiment the panelist just-noticeable-difference ($JND_{.05}$) for added nicotine malate was found to be 7 mg/g tobacco, which is equivalent to 3.7 mg of nicotine per gram of tobacco.

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The two lots of cigarettes made available for this smoking comparison had had nicotine added at a rate of 6 mg/g onto one lot and the equivalent amount of nicotine malate (10.32 mg/g) onto the other lot. All cigarettes had been adjusted to the standard moisture content of 13% ± .5%.

7.2.2 The Smoking Comparisons

Each of the 15 panelists compared the two test cigarettes (nicotine "N" versus nicotine malate "M") in four triangles: NMM, MMN, NNM and MNN. The triangles NMN and MNM were excluded to avoid the middle-position bias and, hence, to elicit the highest detecting ability from the panellists.

Cigarette coding, handling and serving, as well as smoking technique, were the same as explained previously. When a panelist finished with each smoking test in the booth, he was then given the same three cigarettes (under different codes) in a stoppered vial along with a response card. He was instructed to smoke these test cigarettes whenever, wherever, in any order and using any smoking method he might prefer. He was further asked to record the code numbers of the test cigarettes on the card, to circle the odd and to return the response card to the Smoking Laboratory before he would be permitted to take the next (and succeeding) test.

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7.3 Results and Discussion

7.3.1 Free versus Bound Nicotine

If the two forms of added nicotine produce the same effect on smoke flavor, then the panelist's response or ability to detect the odd cigarette would be equivalent to that of chance probability. The average proportion of correct identification of the odd cigarette would be .33. Table 7.1 shows that the panel mean proportion for the in-booth tests was P = .75 with a standard deviation of .189, hence, the proportion of correct identifications significant at the 5% level is "$P_{.05}$" = .33 + 2 x .189 = .71. This indicates that there was, in fact, a detectable difference in smoke flavor (P = .75 vs. $P_{.05}$ = .71) due to the addition of supra-threshold amount of nicotine malate against an equivalent amount of nicotine.

The reason for this difference in smoke flavor cannot be fully explained as the exact mechanism by which bound nicotine is transferred into the mainstream smoke is not fully understood. Theoretically, a cigarette in which a higher portion of nicotine is free would presumably have a higher portion of free nicotine in its smoke (free is more easily distillable into the mainstream smoke). This would in turn change the pH of the said smoke with the possible effect on its sensory properties. In fact, several panelists (and consistently one panelist) who had correctly identified the odd cigarette had described the smoke of the cigarette(s) to which the free nicotine had been added as "harsh" and

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Table 7.1 Panelists' responses[a] in four triangle smoking tests for nicotine versus nicotine-malate cigarettes

Panelist	In-booth	Take-out
AWA	.75	.50
FGA	.75	.25
HCC	.75	.25
GD	.75	.25
RG	1.00	.50
HRH	.50	.50
SNH	.75	.25
BH	1.00	.50
BK	.75	.50
DFM	1.00	.75
DP	.50	.50
DLT	.50	.25
JW	.75	.75
JAW	1.00	1.00
WGW	.50	.50
Panel mean (P)	.75	.48
Standard deviation	.189	.221
Panel ($P_{.05}$)[b]	.711	.775
Panel difference (D)[c]	.27	
t-value (with 28 d.f.)	3.61**	

[a]Proportions of correct identifications of the odd cigarette

[b]Proportion of correct identification significant at the 5% level

[c]Difference between the panel means "in-booth" and "take-out"

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"strong". It may be said that nicotine in the mainstream smoke, whether it is free or bound in the tobacco, satisfies the nicotine appetite of the smoker. The distinction between the two forms, if there is any, may be based on the greater transfer (via distillation) of free nicotine from the tobacco to the mainstream smoke. Nicotine, because of its alkaline nature, raises the pH of the smoke, hence, a cigarette mainstream smoke (which is acidic with a pH 6.3-6.8) would presumably contain less free nicotine than the amount actually distilled. The change in the pH of the smoke would alter its sensory properties (71, 86, 87). In general, smoke from the added free nicotine cigarettes brought about undesirable sensory impressions upon the panelists.

Another criterion that cannot be ignored is the malic acid moiety. The 10.32 mg/g nicotine malate included 4.32 mg malate. Though the concentration of the "native" malate in the flue-cured tobacco used is not known, the percentage of added malate can be arrived at by approximation. In an earlie study (83), it was reported that a flue-cured variety (SC 58, 1959 crop) contained .909 meq malic acid per gram of tobacco; this converts to 94.6 mg/g. Assuming the tobacco used in these tests contained a comparable amount of malate, then the added 10.32 mg nicotine malate increased the malate by approximately 5%. It is not clear whether this increment of malate affects the sensory properties of smoke. In testing the nicotine versus nicotine malate cigarettes, many panelists based their decision on a "stronger" reaction to the nicotine cigarette but they verified their decision by a "nasal"

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reaction from nicotine malate cigarettes. The nasal characteristics may be attributed to the malate since this had been the pronounced difference that several panelists had encountered in the nicotine malate series (section 6.3.2).

The fact that the two forms of nicotine have different effects on the flavor characteristics and possibly the physiological effect of cigarette smoke is of considerable importance in evaluating tobaccos with similar amounts of nicotine. To date most of the results of chemical analyses are expressed in terms of total nicotine (both free and bound). Additional work should be undertaken towards the development of a standard procedure by which the distinction between the two forms of nicotine can be determined and expressed as two separate identities, because their effects on the smoking qualities are presumably different.

7.3.2 Two versus Four Triangles

The consistent performance of panelists in the previous tests suggested that as few as two triangles by 15 panelists would be sufficient to detect any meaningful difference in smoke flavor. Nonetheless, the smoking comparison was carried out by using four triangles (namely NNM, MMN, NNM and MNN), then later it was decided to compare the results from the first two triangles against all four.

Relative to the in-booth tests, the panel mean score was higher in the case of two triangles than in four triangles (Tables 7.1 and 7.2) but both were significant at the 5% level. However, the variability among panelists was higher in the two triangles than in the four as indicated by the

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Table 7.2 Panelists' responses[a] in the first two triangle smoking tests for nicotine versus nicotine malate cigarettes

Panelist	In-booth	Take-out
AWA	1.0	.5
FGA	1.0	.0
HCC	1.0	.5
GD	1.0	.0
RG	1.0	.5
HRH	.5	.5
SNH	.5	.0
BH	1.0	.0
BK	1.0	1.0
DFM	1.0	.5
DP	.5	.0
DLT	.5	.0
JW	.5	.5
JAW	1.0	1.0
WGW	.5	.0
Panel mean score (P)	.80	.30
Standard deviation	.24	.38
Panel ($P_{.05}$)[b]	.81	.99
Panel difference (D)[c]	.50	
t-value (d.f. = 28)	4.2**	

[a]Proportions of correct identifications of the odd cigarette

[b]Proportions of correct identification significant at the 5% level

[c]Difference between the panel mean scores in-booth and take-out

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standard deviations; .241 versus .189, respectively. This clearly indicates that as long as the smoking tests are undertaken by trained panelists under controlled conditions (in the booths) as few as two triangles can suffice.

This is of practical importance because it will reduce the pressure on each individual panelist and, hence, avoid his losing interest in the tests. A sensory analyst must compromise between the proper use of statistics (more replications reduce the error) and psychophysics (more tests imply risk due to discontinuity and loss of interest).

Interest and motivation play a major role in the proper use of a panel in sensory testing. Several methods have been reported (5, 12, 30, 40, 46) for maintaining the necessary degree of interest and motivation among panelists, otherwise the results of sensory testing would be psychologically biased. One major problem in sensory testings conducted over a considerable period of time and/or employing a considerable number of tests per panelist is the difficulty in keeping the subjects interested in the tests and sufficiently motivated to continue.

Several ways were employed to maintain interest and motivation among the panelists, including: (a) Response cards of different colors were used for the different series of smoking comparisons. (b) The potential panelists were informed of the objective of each series of smoking tests, what was to be measured and the practical importance of the information to be obtained (Appendix Figures 1 and 2).

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(c) Each panelist was adequately informed of his results of each series of tests after it had been completed (Appendix Figures 17 and 18). (d) Informal discussions were encouraged between the panelists and the sensory analyst, to let them express their impressions about the tests' procedures and outcomes (Figure 7.1). (e) Coffee, soft drinks and cookies were served to the panelists after taking each smoking test.

In addition, several methods were developed in the course of the experiments to improve the panel performance. The basic principles of psychophysics were explained by the sensory analyst with respect to the effect of external variables (noise) and subject's criterion on the stimulus-response relationship. For example, the theory of the distance model (25) as applied to triangle tests was introduced. This theory states that the subject's response must be related to a geometric model of perceptual space. The distance model is preferred when the panelists are asked to describe a stimulus configuration in as few dimensions as possible (hit or miss). Simply, the panelists were asked to think of a triangle test as three points at "equal" distance in space (Figure 7.2), and the odd cigarette is the one whose smoking characteristics would move it to a distance farther from the other two.

7.3.3 In-booth versus Take-out

With regard to the four-triangle tests, the panel mean proportion of correct identifications was .75 for the in-booth tests compared to .48 for the take-out tests (Table 7.1). The significance of the t-value for the difference between the

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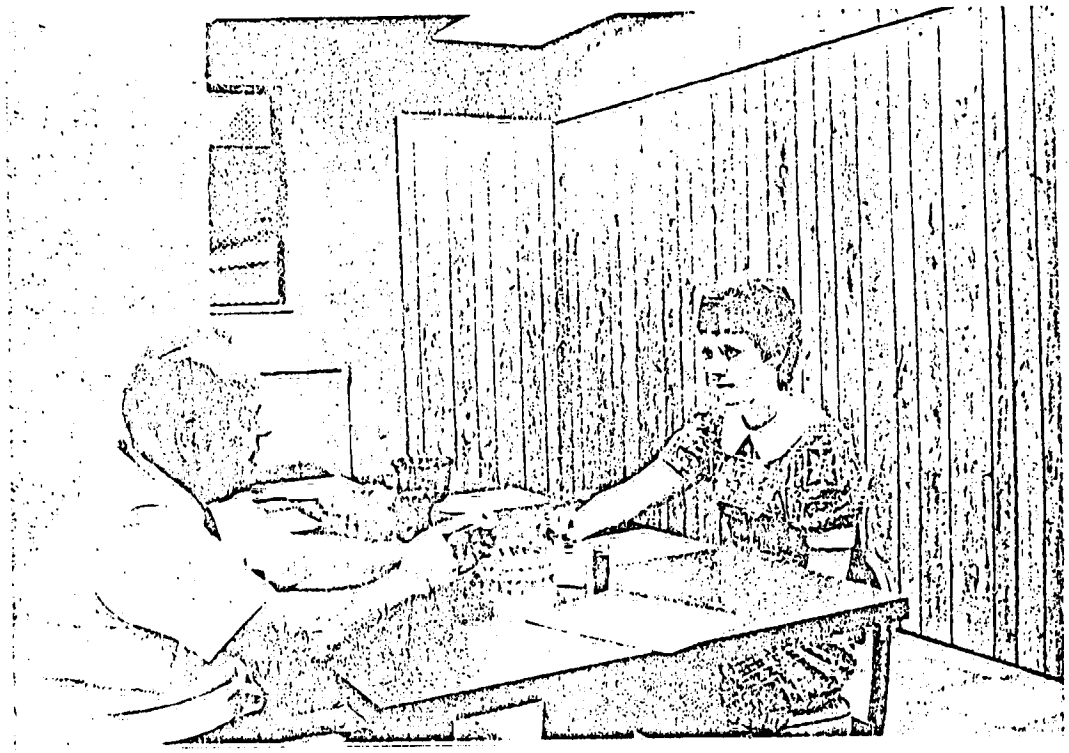

Figure 7.1 Panelist discussing the test results and procedures with the sensory analyst. Booths are closed

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two panel means (in-booth versus take-out) is a direct indication of the superiority of the in-booth environment. In the two-triangle tests (Table 7.2) the contrast between in-booth and take-out was even more pronounced.

The variability among panelists was much smaller in the in-booth tests than in the take-out tests. Of course, the greater variability in the take-out tests was due to the external (unknown) variables which may have influenced the panelist's decision (deliberately or by chance). Since most of the factors influencing both stimulus and non-stimulus variability (such as subject, situation, treatment and task) were somewhat controlled for the in-booth tests, the panelists responded more uniformly from one test to the other and the variability was less. Hence, under controlled conditions in the laboratory the panel was able to detect (beyond the chance probability) differences in the smoking characteristics which were confounded with extraneous (unknown) variables prevailing in the non-controlled conditions under which the panel performed in the take-out tests. Although the performance of this trained panel has proven to be adequate and consistent, it is obvious that the high performance was due not only to the panelists themselves (subjects) or to the type of difference to be detected but also to the three-fold criterion of sensory testing, namely test conditions, test procedure and test materials.

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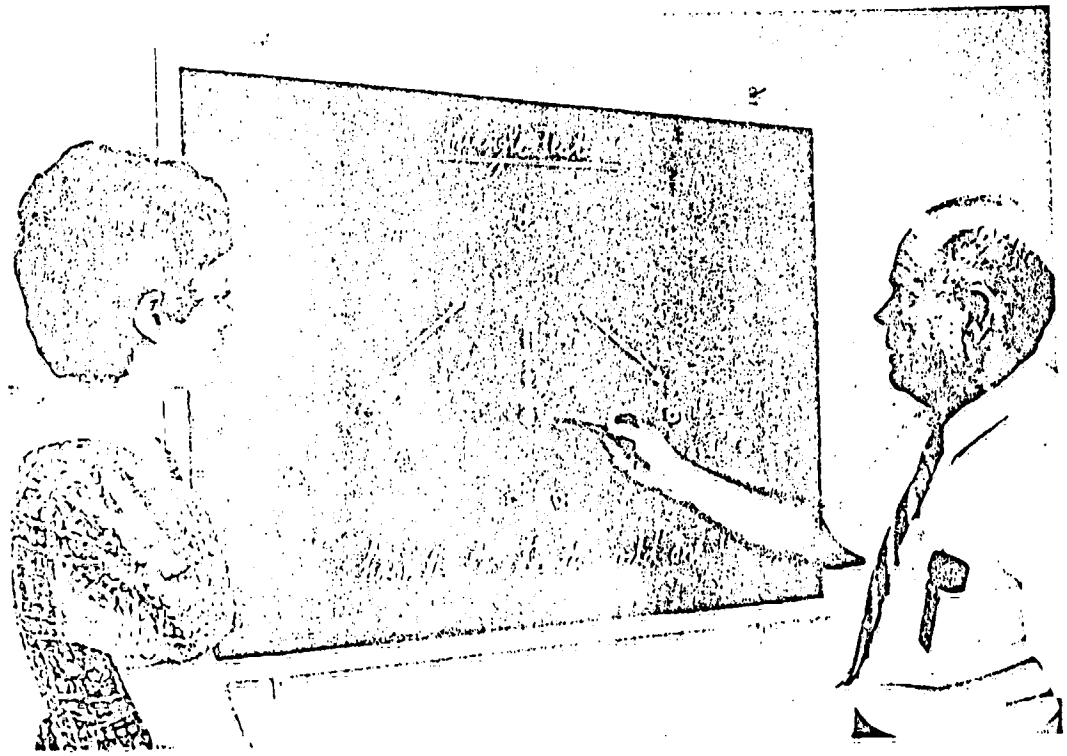

Figure 7.2 The theory of the distance model as applied to triangle smoking tests is explained to the panelists to improve their performance

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8. SUMMARY

The procedure for the selection of a smoking panel from a roster of 93 volunteers (candidates) at North Carolina State University is described. To have 20 trained panelists available for each smoking test, 30 panelists had to be selected. Panel selection was based on the subject's ability to detect three types of differences (blending, casing and flavoring) that might exist during the actual testing of experimental cigarettes. Selection techniques were designed not only to qualify subjects as panelists but also to train them on how to detect differences. The techniques also stressed the importance of an appropriate set of testing materials, testing conditions and testing methods. For example, all smoking tests were conducted in the booths to minimize the influence of extraneous (non-stimulus) variables or "noise" on the subject's response. Two markings on the cigarette were used as a physical method to control the amount of stimulus (smoke). Of the 36 subjects who completed the required smoking tests (15 triangles), 30 individuals demonstrated discriminating abilities greater than the chance probability and thus were qualified as panelists.

As part of the training program, primary taste tests were employed to familiarize the potential panelists with the four taste qualities (sweet, salt, sour and bitter). Each subject's threshold and acuity (sensitivity) value

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were determined. A subject's performance in taste tests in no way compromised his potentiality for selection as a panelist; however, taste tests presumably improve the subject's sensory acuity during the actual testing of cigarette smoke. There were no significant differences between smokers and non-smokers relative to their taste sensitivities except for the acuity to the sour taste.

Correlations between certain pertinent statistics and the discriminating ability of potential panelists in the smoking tests were established. Among the 36 subjects who completed all the required smoking tests, a higher percentage of cigarette smokers qualified as panelists than did pipe and cigar smokers or non-smokers. Within a reasonable amount of time and material, cigarette smokers are more likely to have discriminating ability (hence, to be selected as panelists) than pipe and cigar smokers or non-smokers.

In triangle tests, the panelists respond correctly more often (having greater ability to detect the difference) when the odd cigarette is not in the middle. The effect of the position of the odd cigarette becomes more prominent as the difference becomes smaller (more difficult to detect).

Panel training was continued by measuring the panelist's sensitivity to changes in smoke flavor due to added amounts of sugar and of nicotine malate, each at four different concentrations. Twenty-one panelists completed the sugar series (4 smoking comparisons each in 5 triangles). The

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results indicate that the panel's response to change in smoke flavor due to decreasing amounts of added sugar obeys Weber-Fechner's law, that is, it can be adequately explained by a linear regression on ln (concentration). A method was developed to determine the panel threshold to added amounts of sugar in terms of just-noticeable-difference at the 5% level of significance ($JND_{.05}$). This increment for detection was found to be 11 mg/g of sugar added onto tobacco that already contained 15.8% sugar.

By employing 15 panelists it was found that the relationship between the panel's response to added amounts of nicotine malate also obeys Weber-Fechner's law. The panel $JND_{.05}$ for nicotine malate was 6.8 mg (or 3.65 mg nicotine) per gram of tobacco (with 2.14% of native nicotine). Hence, the magnitude of the difference that our trained panel can detect is 7% for sugar and 17% for nicotine relative to the natural concentrations. In absolute units, however, the panel was more sensitive to nicotine; the detectable increment for nicotine was 3.65 mg/g vs. 11 mg/g for sugar. With proper training the number of performing panelists can be reduced. In one test a panel of 15 trained individuals performed as well statistically as did a panel of 21 (the same 15 plus 6 others). The consistency and homogeneity among the 21 panelists were as significant as those among the 15, and training did help in improving the panel performance.

The 15-member panel was then used to give some information about the qualitative difference in smoke flavor of

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experimental cigarettes to which equivalent supra-threshold amounts of free or bound nicotine (as nicotine malate) had been added. The panel response in four triangles indicated a significant difference in smoke flavor attributed to the two forms of nicotine. Even with employing two triangles the panel was able to detect significantly the difference in smoke flavor.

When panelists were permitted to take the test cigarettes ad libitum (instead of in-booth), the difference in smoke flavor was not detected. The panel discriminating ability was significantly superior in the in-booth than take-out. The variability among panelists was much smaller for the in-booth test than the take-out. Hence, under controlled conditions in the laboratory the panel was able to detect differences in smoke flavor which were not detected in the presence of extraneous variables (non-stimulus) in the take-out situation. This proves that the panel's high performance was not only due to the panelists themselves (training) or to the type and intensity of the difference to be detected, but also to the three-fold criterion of sensory testing: test materials, test conditions and test procedures.

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9. CONCLUDING REMARKS

Because of the extremely complex nature of cigarette smoke and the fact that very little is published on the sensory testing of cigarette smoke, the use of smoking panels as a measuring device constitutes an important, yet most difficult area of study.

The results of this study have emphasized certain factors that materially influence the performance of panels employed in sensory testing of cigarette smoke. Some of these factors merit repeating.

The sensory analyst has to be fully aware of the nature of the problem to be solved and the panel (measuring device) required to solve the particular problem. Of practical importance is his planning of the experiment with respect to test materials, test conditions and test procedures. It is necessary that the investigators understand some of the factors involved in the sensory analysis of their experimental cigarettes. Full cooperation between the sensory analyst and the investigator in determining the sensory technique to be employed and the specifications of the cigarettes to be tested is essential to obtain results as valid as those of physical and chemical tests.

Sensory testing involves the stimulus-response relationship. Stimulus is a physical continuum, whereas response is a psychological one. Most often, a proper experimental design will standardize the factors influencing the stimulus

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under study; however, of utmost importance is the control of the non-stimulus variables (extraneous) that may influence response. Adaptation or fatigue occurs rapidly in smoking, hence, there is a maximum number of cigarettes to be compared in one test (three cigarettes). This will entail larger numbers of sensory tests which will in turn necessitate the subjects participating more often or longer. Methods have to be employed to maintain the subject's interest and motivation in time-course experiments in sensory testing.

In sensory testing of cigarette smoke, the amount of stimulus (smoke) has to be under control and the method by which the stimulus is introduced (smoking technique) has to be standardized. In addition, there exist some psychological errors that are apt to occur unless the experimenter refines his techniques, e.g. using triangle tests to avoid "expectation", code numbers to avoid "association", rotation of the odd to avoid "positional" bias, etc. The sensory analyst is the one responsible for controlling or correcting for both stimulus (under study) variables and non-stimulus (extraneous) variables. Many incorrect findings, such as the non-existence of a detectable difference when there is a detectable difference, are derived from "experimenter error" and not from limitations of human sensory response systems.

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11. APPENDIX

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Appendix Table 1. Concentrations of solutions used in primary taste testings

Solution or level	Salt sodium chloride		Sweet sucrose		Bitter caffeine		Sour tartaric acid	
	Conc.		Conc.		Conc.		Conc.	
	mM/l	g/l	mM/l	g/l	mM/l	g/l	mM/l	g/l
1	1	0.0584	0.5	.1711	.1	.0194	.10	.0150
2	2.5	0.1461	1	.3423	.3	.0582	.16	.0240
3	5	0.2922	2.5	.8558	.5	.0971	.25	.0375
4	7.5	0.4384	5	1.7115	1	.1942	.5	.0750
5	10	0.5845	7.5	2.5672	2	.3884	.75	.1125
6	15	0.8768	10	3.4230	3	.5826	1	.1501
7	20	1.1690	15	5.1345	4	.7768	1.5	.2251
8	25	1.4612	20	6.8460	5	.9710	2	.3000
9	30	1.7535	25	8.5572	6	1.1652	3	.4503
10	35	2.0458	30	10.2690	7	1.3594	4	.6004
11	40	2.3380	35	11.9805	8	1.5536	5	.7500
12	50	2.9225	40	13.6920	9	1.7477	6	.9000
13	75	4.3838	50	17.1150	10	1.9419	7	1.050
14	100	5.8450	75	25.6725	12	2.2304	8	1.200

Molecular weights: sodium chloride 58.49; sucrose 342.3; tartaric acid 150.1; and caffeine 194.9

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Appendix Table 2. Subject's thresholds (mM/l) and acuity values (Kendall's τ) for the four primary tastes

Name	Threshold (mM/l)								Acuity (Kendall's τ)[a]			
	Sweet		Salt		Sour		Bitter					
	DL[b]	RL[c]	DL	RL	DL	RL	DL	RL	Sweet	Salt	Sour	Bitter
AWA	5	15	10	25	.5	1.00	.5	2	.40	.60	.67	.93
FGA	5	10	10	20	.25	.75	.5	2	1.00	.93	.87	.93
JWB												
SWB												
HCC	7.5	20	7.5	15	.25	.75	2.0	3	.87	.87	.93	.93
GD	2.5	20	5	20	.16	.75	.3	3	.67	1.00	.93	.73
MME												
RF												
RG	7.5	15	5	10	.5	1.00	1.0	3	.87	.87	1.00	.87
HRH	2.5	10	5	10	.25	.50	.5	2	.47	.93	.87	.87
SNH	5	10	5	7.5	.16	.25	.5	2	.60	.93	.87	.80
BH	2.5	7.5	5	10	.16	.50	.5	2	1.00	.87	.93	.93
KKK	2.5	5	2.5	5	.10	.75	.3	.50	.73	1.00	.90	.80
BK	5	10	7.5	15	.50	1.50	1.0	2	.93	.80	1.00	1.00
RCL	5	7.5	7.5	20	.50	.75	.3	1	.87	1.00	1.00	.93
TJM	5	10	7.5	20	.16	.25	.5	2	.73	1.00	1.00	.80
DFM	10	15	15	20	.25	.50	2.0	4	.93	.80	.87	.67
DP	5	10	7.5	15	.25	.50	.3	.50	1.00	1.00	.80	.80
GFP	5	20	5	15	.16	.50	.3	3	.90	.80	.93	.80
RP	7.5	20	10	15	.25	.50	.5	4	.93	.87	.87	.93
HLP	10	15	7.5	15	.25	.50	2.0	3				
TWR	5	7.5	5	7.5	.16	.25	.3	.50				
HMS	10	15	7.5	15	.50	.75	2.0	3	.93	1.00	1.00	.93
RS	7.5	10	7.5	10	.25	.50	1.0	2	.67	.67	.93	.87

(continued)

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Appendix Table 2. (continued)

Name	Sweet		Salt		Sour		Bitter		Acuity (Kendall's τ)[a]			
	DL[b]	RL[c]	DL	RL	DL	RL	DL	RL	Sweet	Salt	Sour	Bitter
DLT	5	15	5	10	.25	.50	1.0	2	.67	.67	.93	.87
JW	7.5	20	7.5	7.5	.25	.50	.50	5	1.00	.93	.93	1.00
FRW	7.5	20	10	20								
WWW	2.5	5	10	15	.25	.50	.50	.50	.40	.87	.93	.53
JAW	7.5	10	7.5	30	.25	.50	.30	1	.73	.47	.87	.53
TBW	10	15	5	15	.25	1.00	1.0	2	.90	1.00	1.00	1.00
HUW												
WGW	2.5	5	5	10	.25	.75	.30	3	.47	.40	.80	.83
JWW												
RY												
EKY	5	15	5	10	.16	.50	.30	2	.90	.93	.93	.70
$\bar{x}$	4.6	12	5.5	14	.21	.6	.57	2	.789	.853	.910	.834

[a]Rank correlation coefficient, average of three tests

[b]Detection threshold in mM/l, average of three tests

[c]Recognition threshold in mM/l, average of three tests

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Appendix Table 3. Correlation between the subjects' acuity values to the four primary tastes

	Sweet		Salt		Sour		Bitter	
	RL[a]	τ[b]	RL	τ	RL	τ	RL	τ
Sweet RL		.40*	NS[c]	NS	NS	NS	.47**	NS
Sweet τ			NS	.42*	NS	.44*	NS	.47**
Salt RL				NS	.32	NS	NS	NS
Salt τ					NS	.49**	NS	NS
Sour RL						NS	.30	.46*
Sour τ							NS	NS
Bitter RL								NS
Bitter τ								

[a]Recognition threshold in mM/l

[b]Rank correlation coefficient in terms of Kendall's τ

[c]Not significant

Appendix Table 4. Chi-square test of the subjects' acuity values to the four primary tastes

	Sweet		Salt		Sour		Bitter	
	RL[a]	τ[b]	RL	τ	RL	τ	RL	τ
Sweet RL		NS[c]	NS	NS	NS	NS	15**	NS
Sweet τ			NS	12*	NS	11*	NS	12*
Salt RL				17**	NS	13*	NS	NS
Salt τ					NS	NS	NS	NS
Sour RL						NS	9.8*	NS
Sour τ							NS	NS
Bitter RL								NS
Bitter τ								

[a]Recognition threshold in mM/l

[b]Rank correlation coefficient in terms of Kendall's τ

[c]Not significant

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Appendix Table 5. Comparison between primary taste sensitivity of smokers versus non-smokers

Sweet				Salt				Sour				Bitter			
RL[a]		τ[b]		RL		τ		RL		τ		RL		τ	
S[c]	NS[d]	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
15	10	.40	1.00	25	20	.60	.93	1.00	.75	.67	.87	2	2	.93	.93
20	10	.87	.93	15	15	.87	.80	.75	1.50	.93	1.00	3	2	.93	1.00
20	7.5	.67	.87	20	20	1.00	1.00	.75	.75	.93	1.00	3	1	.73	.93
10	15	.87	.80	15	10	.87	.80	.25	.50	1.00	.93	2	2	.87	.93
15	5	.47	.40	10	15	.93	.87	.75	.50	.87	.93	3	.5	.67	.53
15	15	.60	.93	10	15	.93	1.00	1.00	1.00	.87	1.00	3	2	.80	1.00
10		1.00		10		.87		.50		.93		2		.93	
10		.73		7.5		1.00		.25		.90		2		.80	
7.5		.73		10		1.00		.50		1.00		2		.80	
5		.93		5		.80		.25		.87		.5		.67	
10		1.00		20		1.00		.25		.80		2		.80	
15		.90		20		.80		.50		.93		4		.80	
10		.93		15		.87		.50		.87		.5		.93	
20		.93		15		1.00		.50		1.00		3		.93	
20		.67		15		.67		.50		.93		1		.87	
15		1.00		15		.93		.50		.93		3		1.00	
7.5		.73		7.5		.47		.25		.87		.5		.53	
15		.47		15		.40		.75		.80		3		.83	
10		.90		10		.93		.50		.93		2		.70	
20				7.5				.50				1			
10				30				.50				1			
5				10				.75				3			
15				10				.50				2			
10				15				1.00				1			
10				15				.75				3			

(continued)

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Appendix Table 5. (continued)

	Sweet				Salt				Sour				Bitter			
	RL[a]		τ[b]		RL		τ		RL		τ		RL		τ	
	S[c]	NS[d]	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
n	25	6	19	6	25	6	19	6	25	6	19	6	25	6	19	6
$\bar{x}$	12.8	10.4	.78	.82	13.9	15.9	.84	.90	.57	.83	.90	.96	2.14	1.58	.82	.88
d.f.	29		23		29		23		29		23		29		23	
t[e]	1.142		.432		.866		.815		1.99		1.74		1.11		.96	

[a]Recognition threshold in mM/l

[b]Acuity value in terms of rank correlation coefficient, Kendall's τ

[c]Smokers

[d]Non-smokers

[e]True value of t for the difference between two means. All values are not significant

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Appendix Table 6. Comparisons between primary taste sensitivity of selected cigarette smokers versus non-smokers

	Sweet				Salt				Sour				Bitter			
	RL[a]		τ[b]		RL		τ		RL		τ		RL		τ	
	CS[c]	NS[d]	CS	NS	CS	NS	CS	NS	CS	NS	CS	NS	CS	NS	CS	NS
	20	10	.67	1.00	20	20	1.00	.93	.75	.75	.93	.87	3	2	.73	.93
	10		.47	.93	15	15	.93	.80	.25	1.50	.87	1.00	2	2	.67	1.00
	10	10	.60	.87	10	20	.93	1.00	.50	.75	.87	1.00	2	1	.80	.93
	10	7.5	1.00	.80	7.5	10	.87	.80	.25	.50	.93	.93	2	2	.93	.93
	7.5	15	.73	.40	10	15	1.00	.87	.50	.50	.90	.93	2	.5	.80	.53
	5	5	.93	.93	5	15	.87	1.00	.25	1.00	.87	1.00	.5	2	.93	1.00
	20	15	1.00		15		.93		.50		.93		1		1.00	
	15		.47		15		.40		.50		.80		3		.83	
	20		.90		5		.93		.50		.93		1		.70	
	5				7.5				.75				3			
	15				7.5				.50				2			
	10				15				1.00				1			
	10				15				.75				3			
n	13	6	9	6	13	6	9	6	13	6	9	6	13	6	9	6
$\bar{x}$	12.1	10.4	.75	.82	12.1	15.9	.87	.90	.55	.83	.89	.96	1.96	1.58	.82	.88
d.f.	17		13		17		13		17		13		17		13	
t[e]	.62		.61		1.61		.37		2.06		2.78*		.87		.80	

[a]Recognition threshold in mM/l

[b]Acuity value in terms of rank correlation coefficient, Kendall's τ

[c]Those over 21 years old and who smoke 20 cigarettes or more per day

[d]Non-smokers

[e]True value of t for the difference between two means

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Table 7. Statistical information covering the 36 subjects who completed all required smoking tests for panel selection and training

Name	Sex	Age	Group[a]	Yrs. smk.[b]	Type	Cig./day[c]	SMKINT[d]	Total score[e]
AWA	M	26	S	9	Cigarette	17	2	9
FGA	M	40	NS		Chew		0	9
JWB	M	38	NS				0	8
SWB	M	38	S	20	Pipe-Cigar		6	12
MCC	M	59	S	41	Pipe-Cigar		6	11
GD	F	22	S	5	Cigarette	20	1	10
EE	M	46	S	20	Cigarette	12	2	9
MME	M	42	S	23	Cigarette	25	3	11
RF	M	42	S	25	Cigarette	25	4	13
RG	M	40	S	15	Cigarette	10	2	14
HRH	M	34	S	13	Cigarette	25	3	10
SNH	M	51	S	35	Cigarette	30	5	11
BH	F	43	S	27	Cigarette	40	5	13
KKK	M	25	S	7	Cigarette	25	5	8
BK	M	35	S	2	Pipe-Cigar		6	9
RCL	M	32	NS				0	13
TJM	M	51	S	31	Pipe-Cigar		6	12
DFM	M	43	S	23	Pipe-Cigar		6	9
DP	M	33	S	14	Cigarette	15	2	11
GFP	M	30	S	12	Cigarette	15	2	9
RP	M	23	S	5	Cigarette	30	2	9
HLP	M	37	S	20	Cigarette	40	4	9
TWR	M	24	S	5	Pipe-Cigar		6	7
HMS	F	29	S	10	Cigarette	5	1	9
RS	M	33	S	20	Pipe-Cigar		6	9
DLT	M	36	NS				0	9
JW	M	28	S	13	Cigarette	30	3	9
FRW	M	22	S	4	Pipe-Cigar		6	10
WWW	M	40	NS				0	9
JAW	M	57	S	40	Pipe-Cigar		6	12
TBW	M	33	NS				0	9
HUW	F	49	S	20	Cigarette	30	4	7
WGW	M	61	S	40	Cigarette	30	5	10
JWW	M	21	NS				0	8
RY	M	45	S	25	Pipe-Cigar		6	6
EKY	M	25	S	5	Cigarette	20	1	10

[a] S = smokers and NS = non-smokers

[b] Number of years the subject has been smoking

[c] Number of cigarettes the subject smokes per day

[d] SMKINT = (years of smoking x number of cigarettes/day)/100, with pipe and cigar smokers assigned a temporary class value of 6, and non-smokers a zero value

[e] Total number of correct identification of the odd cigarettes in 15 triangles

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Table 8. Analysis of variance, regression of SMKINT-C on average score in triangle smoking tests for panel selection and training

Source	All subjects			Panelists		
	df	SS	F	df	SS	F
Comparison	2	3.24	3.6*	2	2.87	3.19*
SMKINT-C	1	2.09	4.6*	1	1.97	4.39*
Name (SMKINT)	29	36.13	2.7**	23	20.99	2.03**
Error	75	33.75		63	28.27	
Total	107	75.21		89	54.10	
Intercept		3.09 ± .1049			3.19 ± .1344	
b value		.096 ± .0444			.097 ± .0462	

2028559741

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Table 9. Subjects' scores[a] in smoking comparisons for panel selection and training

Name	Smoking comparison			Total
	A-B	B-C	C-D	
AWA	3	3	3	9
FGA	3	4	2	9
JWB	3	2	3	8
SWB	4	4	4	12
HCC	5	3	3	11
GD	3	4	3	10
EE	3	3	3	9
MME	4	4	3	11
RF	5	4	4	13
RG	5	5	4	14
HRH	3	4	3	10
SNH	4	3	4	11
BH	5	3	5	13
KKK	4	2	2	8
BK	3	4	2	9
RCL	5	4	4	13
TJM	4	4	4	12
DFM	3	2	4	9
DP	4	3	4	11
GFP	4	3	2	9
RP	3	3	3	9
HLP	3	3	3	9
TWR	2	3	2	7
HMS	3	3	3	9
RS	5	2	2	9
DLT	3	3	3	9
JW	3	3	3	9
FRW	2	4	4	10
WWW	3	3	3	9
JAW	4	5	3	12
TBW	3	3	3	9
HNW	3	2	2	7
WGW	4	3	3	10
JWW	2	3	3	8
RY	2	2	2	6
EKY	4	3	3	10
$\bar{x}$ (36)[b]	3.50	3.22	3.08	9.81
$\bar{x}$ (30)[c]	3.67	3.40	3.23	10.30

[a]Number of correct identifications of the odd cigarette in each comparison (5 triangles)

[b]Means of scores of all 36 subjects who completed the required 15 triangles

[c]Means of scores of those subjects with total score of 9 or more (30 panelists)

2028559742

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Table 10. The subjects' identification[a] of the odd cigarette in smoking tests (3 comparisons x 5 triangles) for panel selection and training

Name	Total score	A-B					B-C					C-D				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
AWA	9	1	0	1	0	1	1	0	1	1	0	0	1	1	1	0
FGA	9	0	0	1	1	1	1	0	1	1	1	0	0	1	1	0
JWB	8	1	1	1	0	0	0	0	1	1	0	1	1	1	0	0
SWB	12	1	1	1	1	0	1	0	1	1	1	1	0	1	1	1
HCC	11	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1
GD	10	1	0	1	1	0	1	1	1	1	0	1	0	1	1	0
EE	9	1	1	1	0	0	1	0	1	1	0	1	1	0	1	0
MME	11	1	0	1	1	1	1	1	1	1	0	1	1	0	1	0
RF	13	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1
RG	14	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
HRH	10	1	1	0	1	0	1	1	1	0	1	0	0	1	1	1
SNH	11	0	1	1	1	1	1	1	1	0	0	1	0	1	1	1
BH	13	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
KKK	8	0	1	1	1	1	0	0	1	1	0	1	0	0	1	0
BK	9	1	1	0	1	0	1	0	1	1	1	0	0	1	1	0
RCL	13	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0
TJM	12	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1
DFM	9	0	0	1	1	1	1	1	0	0	0	0	1	1	1	1
DP	11	1	1	1	1	0	1	0	1	1	0	1	1	1	1	0
GFP	9	1	1	1	1	0	1	1	1	0	0	1	0	1	0	0
RP	9	1	0	1	1	0	0	1	0	1	1	0	0	1	1	1
HLP	9	1	1	0	1	0	1	0	1	1	1	0	1	1	1	0
TWR	7	1	0	0	1	0	1	0	1	0	1	1	0	0	1	0
HMS	9	1	1	1	0	0	1	1	1	0	0	1	0	1	1	0
RS	9	1	1	1	1	1	0	0	1	0	0	0	1	1	0	1
DLT	9	0	0	1	1	1	0	1	1	1	0	1	0	0	1	1
JW	9	0	0	1	1	1	0	1	1	1	0	1	0	1	0	1
FRW	10	0	0	1	0	1	1	1	1	1	0	1	1	1	0	1
WWW	9	1	0	1	1	0	1	0	0	1	1	1	0	1	1	0
JAW	12	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
HNW	7	1	0	1	1	0	0	0	0	1	1	1	0	0	1	0
TBW	9	0	0	1	1	1	1	0	1	1	0	1	0	1	0	1
WGW	10	1	1	1	0	1	1	0	1	0	1	1	0	1	0	1
JWW	8	1	1	0	0	0	1	0	1	1	0	1	1	0	1	0
RY	6	1	0	0	1	0	0	0	0	1	1	0	0	1	1	0
EKY	10	1	1	1	0	1	0	1	0	1	1	1	0	1	1	0
Subjects		28	21	29	28	20	27	17	27	28	16	26	14	28	28	16
Panelists		23	18	26	24	19	25	17	23	23	13	21	12	26	23	16

[a]Given the value "1" for correct identification and zero otherwise.

2028559743

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Table 11. Panelists' scores[a] as affected by the position of the odd cigarette in triangle smoking tests for panel selection and training

Smoking comparison	Triangles 1 FFS	2 FSF	3 SFF	4 SSF	5 SFS
A-B	23	18	26	24	19
B-C	25	17	23	23	13
C-D	21	12	26	23	16
Total	69	47	75	70	48
Mean[b]	.77	.52	.83	.78	.53

$LSD_{.05}$ = .062 C.V. = 65%

[a]Number of correct identifications of the odd by all panelists in each of the 15 triangle smoking tests

[b]Mean score of the 30 panelists in the 3 comparisons-mean = total/30/3

2028559744

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Table 12. Effect of odd position on the proportion[a] of panelists' score in triangle smoking tests for panel selection and training

Smoking comparison	Triangle 1 FFS	2 FSF	3 SFF	4 SSF	5 SFS	Total
A-B	21	17	24	22	16	100
B-C	24	16	23	23	14	100
C-D	22	12	27	23	16	100

[a]Proportion (%) of the number of correct identifications of all panelists in a triangle to the total score in the five triangles

Appendix Table 13. Combined effect of odd position (middle versus others) on panelists' response in triangle smoking tests for panel selection and training

Smoking comparison	Totals (1, 3, 4)[a]	Totals (2, 5)[b]	Proportion (1, 3, 4)	Proportion (2, 5)
A-B	73	37	66	34
B-C	71	30	70	30
C-D	70	28	71	29

[a]Combined scores (or proportions) of all panelists in the three triangles FFS, SFF and SSF

[b]Combined scores (or proportions) of all panelists in the two triangles FSF and SFS

2028559745

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 1. Memorandum to the tobacco staff, North Carolina State University, explaining the objectives of the panel program and asking for volunteers

2028559746

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

School of Agriculture and Life Sciences
Agricultural Experiment Station
Box 5847 Zip 27607

August 9, 1971

MEMORANDUM TO: Tobacco Staff

FROM: Kenneth R. Keller

Flue-cured tobacco production is in a period of change. Mechanized harvesting appears to be imminent. Other potential modifications to accommodate mechanical harvesting such as more uniformly ripening varieties, low topping, fewer and heavier croppings, ripening agents, and the bulk curing of leaf pieces are all under investigation. It is hardly conceivable that certain of these changes would not affect smoking flavor to some degree. Since laboratory analyses of cured leaf is still inadequate for predicting smoke flavor, the decision has been made to reinstitute panel smoking.

North Carolina State University is uniquely equipped for the panel evaluation of experimental tobaccos. We have the talent--you; we produce the experimental tobaccos; we have the advice of competent statisticians and the facilities of the Computing Center. Even more important, we have a vested interest in the future of tobacco.

The purpose of this memorandum is to ask you to volunteer your services to the panel by filling out the attached questionnaire. (Additional questionnaires are available for other volunteers from your group.) It is anticipated that participation would average no more than 30 minutes per week and would be scheduled to interfere minimally with your regular activities.

Mr. Fawky Abdallah, formerly with the Eastern Tobacco Company, Cairo, and author of the book "Tobacco Quality: Can It Be Measured?", has been appointed Research Assistant with Dr. Weybrew. Because of his interest and experience in sensory testings, Mr. Abdallah will conduct the tests under the supervision of Drs. Weybrew and Monroe. Your full and enthusiastic cooperation is solicited.

KRK:sh

Attachment

2028559747

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 2. Informing the people of the importance of the research program and of the contribution it will add, would presumably increase each individual's motivation and elicit his interest in participating in the panel project

2028559748

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

School of Agriculture and Life Sciences

Department of Crop Science
Box 5155 Zip 27607

June 26, 1972

MEMORANDUM TO: Faculty, Staff, and Graduate Students in SALS

FROM: J. A. Weybrew

SUBJECT: Request for Volunteers to Serve on Smoking Panel

Do cigarettes all taste alike to you? If not, we need your special talents on our smoking panel. (But even if you are uncertain about your ability to taste differences, we still may be able to "train" your palate to distinguish among imposed differences in kind and intensity of flavors.)

U. S. flue-cured tobacco continues to be in demand the world over because of the superior flavor it imparts to the smoke of cigarettes. But changes in production methods, some of which conceivably could alter flavor, are in the offering. The dwindling labor supply will force mechanization and, to accommodate these machines, production practices and especially curing methods will be modified. To date, no analytical laboratory is capable of determining the flavor quality of a tobacco; about 2/3 of the 1200 compounds that have been identified in smoke do not occur in the tobacco but are generated during the smoking process. Furthermore, none of the analyzable constituents of smoke itself can be firmly correlated with the smoker's taste impression. Thus it becomes necessary to rely on a smokers panel for the flavor evaluation of experimental tobaccos.

Though uncompensated, participation on the smokers panel is a fully sanctioned activity. We anticipate that your participation would require no more than 30 minutes per week on the average, and we will attempt to schedule you so as to interfere minimally with your regular duties.

Room 206, Agronomy Headhouse (the small two-story brick building behind Williams Hall) has been refurbished as the Smoking Laboratory. We invite you to visit this new facility (at the head of the stairs, turn right -- the Laboratory is at the end of the hall). While there, Mr. Fawky Abdallah, who will be supervising the testing, will be pleased to answer your questions and to outline the testing procedures. Before leaving, we would hope that you would have been persuaded to volunteer your services on the panel.

2028559749

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 3. Some pertinent statistics about each volunteer are supplied by a questionnaire.

2028559750

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

QUESTIONNAIRE

Please answer the following questions, fold, staple, and put in campus mail.

Name: _____ Age: ___(years) Sex: (M) (F)

Campus address: _____ Campus phone _____

Do you smoke? yes ___ no ___ (if yes, proceed)

What do you smoke? cigarettes ___ cigars ___ pipe ___

How long have you been smoking? ___(years)

How old were you when you started smoking? ___(years)

What was the product? cigarettes ___ cigars ___ pipe ___

Do you enjoy smoking? yes ___ no ___

Is your enjoyment associated with any specific activity?

after meals ___ with coffee ___ with drinks ___

others (specify) _____

At what time of day do you smoke most?

morning ___ afternoon ___ noon ___ evening ___

Do you usually inhale the smoke? yes ___ no ___

Have you ever noticed a change in smoke flavor or taste?

yes ___ no ___

Do you ever experience a sense of having smoked too much?

never ___ seldom ___ often ___

How would you describe the sensation of "too much smoking"?

"fatigue" ___ throat "tickle" ___ bitter "aftertaste" ___

others (specify) _____

** FOR CIGARETTE SMOKERS ONLY **

How many cigarettes do you smoke per day? ___ cigarettes

What is the cigarette? _____

Thank you!

2028559751

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 4. A letter addressed to each candidate expressing appreciation for his willingness to cooperate and asking him to indicate the time(s) he might be available

2028559752

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

School of Agriculture and Life Sciences

Department of Crop Science
Box 5155 Zip 27607

MEMORANDUM

TO: _____, Candidate, University Smokers Panel

FROM: Fawky Abdallah

SUBJECT: Time Schedule

We deeply appreciate your willingness to serve on our Smokers' Panel; we believe that you will find the experience interesting.

To minimize our interference with your regular duties, please indicate by check marks on the enclosed card those half-hour periods during the week when you might prefer to be available. If you provide us with several choices, we can more quickly set up a mutually satisfactory schedule.

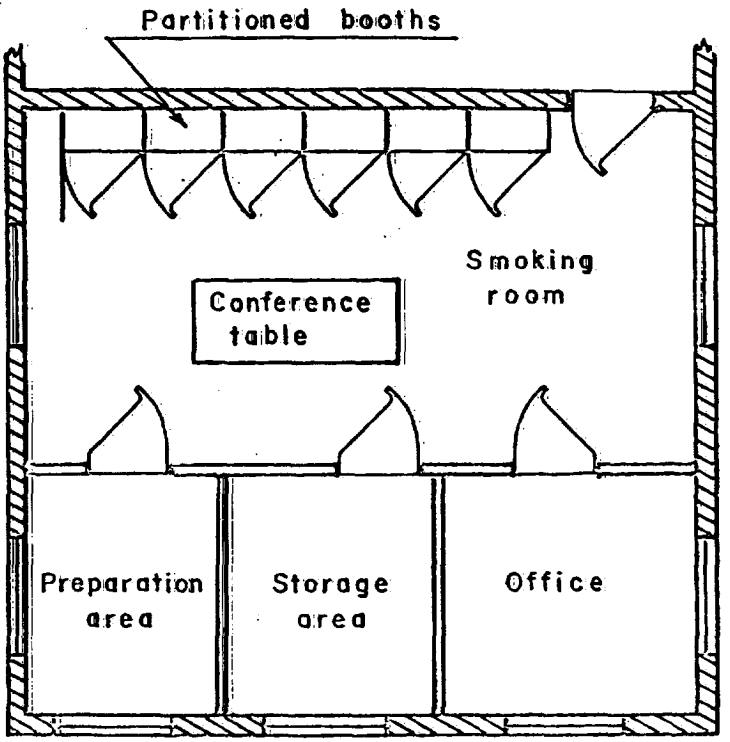
When we get ready to run a test, we will telephone you suggesting that you report at one of the times you have indicated. If, for whatever reason, that time is not convenient, an alternative time could be decided during the same conversation.

Simply drop the card into the campus mail; it is pre-addressed.

Thank you.

2028559753

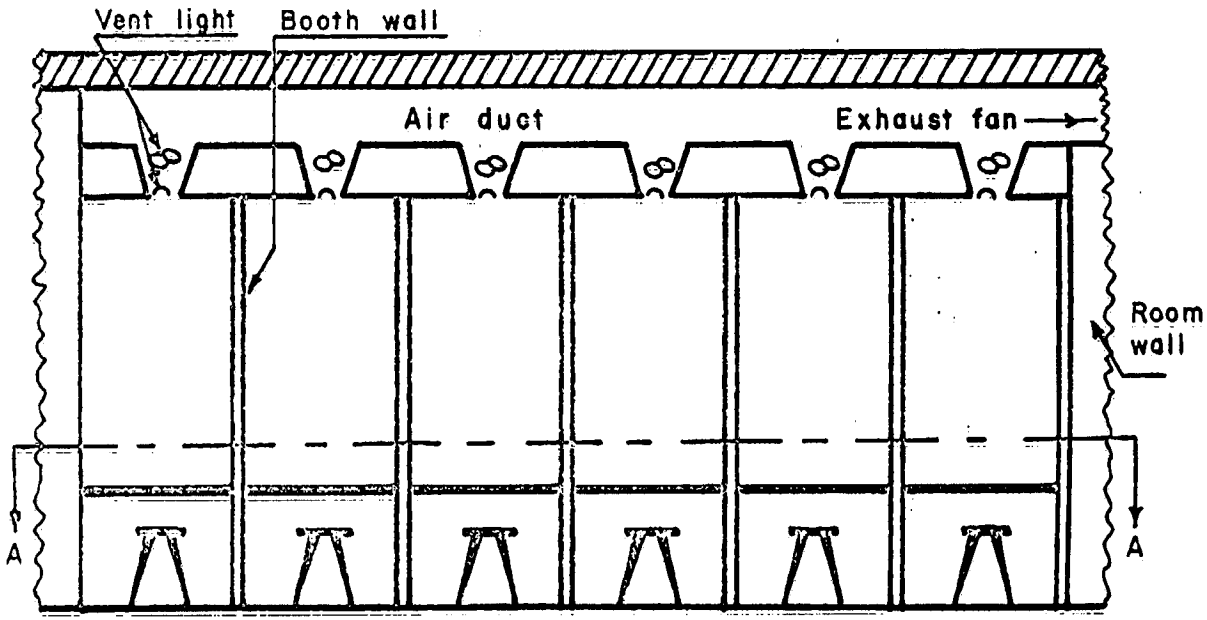
Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000



Appendix Figure 5. Layout of the Smoke Evaluation Laboratory

2028559754

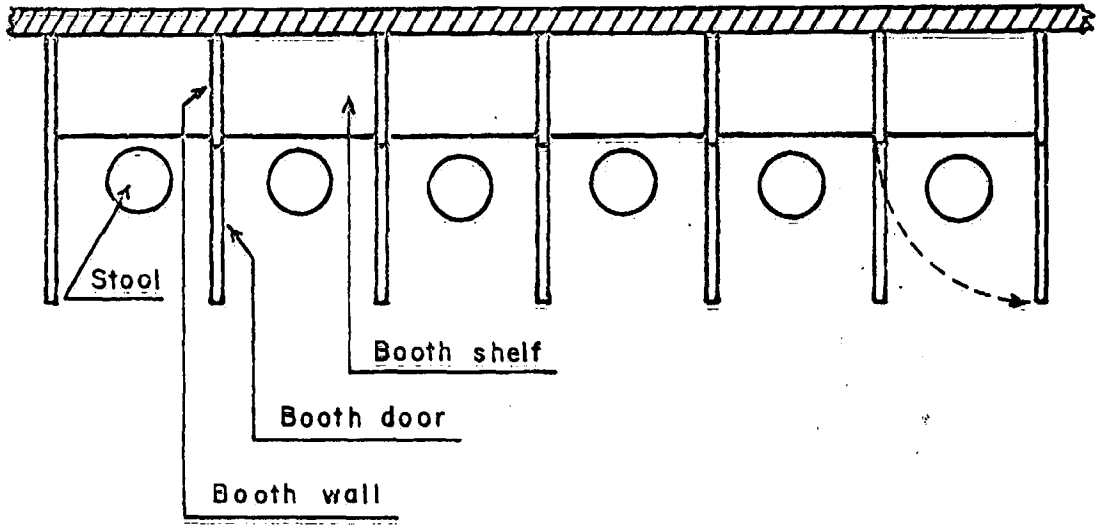
Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000



Appendix Figure 6. Smoke Evaluation Laboratory; elevation of the six-partitioned booths and the main duct (booth doors are opened and stools in)

2028559755

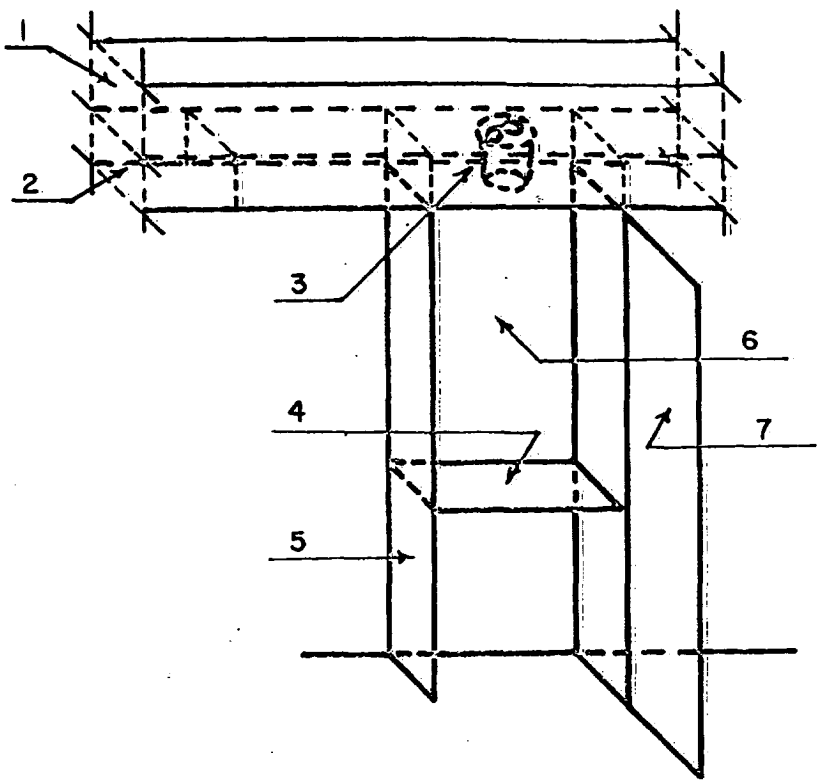
Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000



Appendix Figure 7. Smoke Evaluation Laboratory; sectional plan A-A of Appendix Figure 6

2028559756

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000



1 Main air duct
2 Housing of vent light
3 Vent light
4 Booth shelf
5 Booth wall
6 Room wall
7 Booth door

Appendix Figure 8. Perspective view of a smoking booth

2028559757

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 9. Instruction sheet for threshold determination by the method of limits

2028559758

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Threshold Determination

Procedure

I. Nine solutions are presented to you in order of increasing concentration, plus a cup of distilled water. Please taste the solutions, one at a time, following the order of presentation.

II. Firstly, taste the water in the left cup taking a small amount into the mouth; swish around so that it reaches the back part of the tongue and pharynx. Mentally register your impression about the taste. (Notice that water elicits no taste response, i.e. tasteless. It is important to build up a reaction that enables you to think of distilled water as tasteless).

III. Taste solution No. 1. Mentally register any change in "taste". Spit it into the waste receptacle. Rinse the mouth with water, wait a few seconds then taste solution No. 2 and continue through the series until you arrive at a solution in which you can DETECT a change (difference) in taste. Circle the number of this solution immediately on the response card.

IV. Continue through the series, as above, until you arrive at a solution in which you can RECOGNIZE a definite taste. Circle the number of this solution and the word describing the taste on the response card.

V. The test will be repeated three times. To avoid any bias that may occur due to sample-positioning (correlating taste-level with sample position), the series of solutions may be lowered (or raised) at any time such that the same position may not occur in two consecutive tests.

You may keep this memo to familiarize yourself with the nature of the test.

2028559759

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

THRESHOLD

Name:_____ Date:_____ Time:_____ Test No.:___

Solution at which you can DETECT a change in taste

1 2 3 4 5 6 7 8 9

Solution at which you can RECOGNIZE a certain taste

1 2 3 4 5 6 7 8 9

What is the taste? (Check one)

Sweet Sour Salt Bitter

Appendix Figure 10. Response card for threshold determination by the method of limits

2028559760

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 11. Instruction sheet for the determination of acuity (sensitivity) value by the ranking method

2028559761

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Acuity (Sensitivity) Test

Procedure

I. Five solutions of a certain taste substance (identified) are presented to you in random array. Included in this series are your threshold, two concentrations below your threshold level for this substance, and two higher concentrations. You are requested to taste these solutions, one at a time, and arrange them in order of increasing intensity on the response card.

II. It is recommended to rinse the mouth thoroughly with distilled water (identified) before you start with the test. Taste any one of the five samples, swish the solution around so that it reaches the back part of the tongue and pharynx, put the cup aside and try to register (memorize) its intensity. Spit the solution into the waste receptacle.

III. Rinse the mouth with distilled water, wait a few seconds and try another solution. Register its taste intensity and place it accordingly to the left or right of the previous one (such that, it is having less or more intensity).

IV. Continue with the remaining solutions using the same methodology. You are welcome to check the intensity of any solution (previously tested) if this will help you in "placing" a new one. Avoid guessing.

V. The test will be repeated three times.

You may keep this memo to familiarize yourself with the nature of the test.

2028559762

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

SENSITIVITY

Name:_____ Date:_____ Time:_____ Test No.:___

Substance:_____

Least Intensity Most Intensity

_____, _____, _____, _____, _____

Appendix Figure 12. Response card for the determination of acuity (sensitivity) value by the ranking method

2028559763

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 13. Smoking technique for use in detecting differences by the triangle method

2028559764

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

TRIANGLE SMOKING TESTS

Procedure

Three cigarettes are presented to you on the ash tray in a specific order. Two of these cigarettes are alike (the same). You are kindly asked to "smoke" these cigarettes and determine: which one is unlike the other two, (odd)?

First: Light the three cigarettes, one after the other, using the cigarette lighter provided in the booth. Please light each cigarette from the correct end (opposite the code number) and place it back on the ash tray.

Second: "Taste" the first (far left) cigarette as and when the burning zone approaches the first mark, using the following smoking procedure:

(1) All findings should be based on 3-4 puffs and there should be no inhalation!

(2) The first puff is taken into the mouth and then exhaled from the mouth. At this stage you will be dealing with the process of getting the first impression.

(3) A second and third puff are drawn into the mouth and exhaled slowly through the nose. This is the stage of DETECTION and/or RECOGNITION of certain particular sensory impressions in the smoke flavor. Impressions are registered mentally (memorized!).

(4) Place the cigarette on the ash tray opposite its original position and smoke the second, then the third cigarette following the same procedure.

Third: By now, you have the three cigarettes on the opposite side of the ash tray. If you have already decided which cigarette is the odd, please circle its number on the response card. You may take a fourth puff from each cigarette, if it is necessary to determine which is the odd cigarette. You should finish the test (identify the odd) before the burning zone reached the second mark.

Avoid comparing the test cigarettes with your favorite brand (which you ordinarily smoke) but rather concentrate on inter-comparing the test cigarettes with each other to detect difference.

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

The smoke flavor of the test cigarettes is varied by blending and/or addition of a standard flavoring material - the cigarettes are homogenous except for this added material.

Remember! A panelist trained with the knowledge of the smoking technique employed is much more accurate and reliable and, therefore, can detect smaller differences than an untrained smoker.

You cam keep this memo to familiarize yourself with the nature of the test.

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

SMOKE TEST

Name:_____ Date:_____ Time:_____ Test No.:___

Which one is the ODD cigarette?

(circle one)

912 , 756 , 365

Appendix Figure 14. Response card for triangle smoking tests

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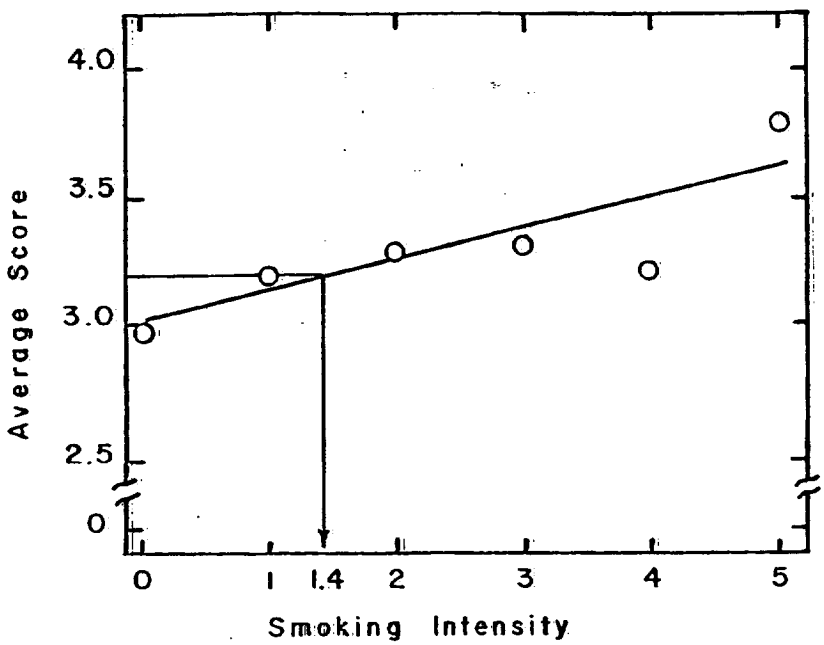
Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000



Appendix Figure 15. Reassigning smoking intensity value for pipe and cigar smokers (among all 36 subjects) by employing their average score

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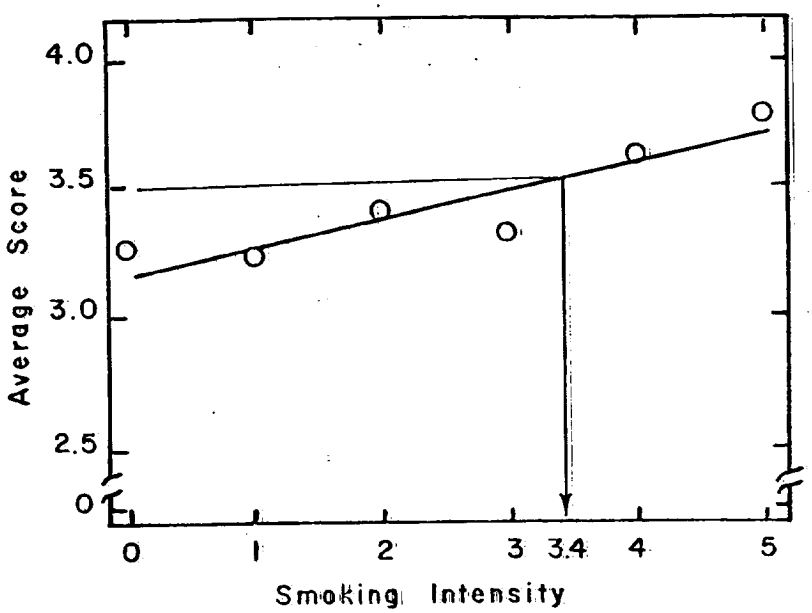
Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000



Appendix Figure 16. Reassigning smoking intensity value to pipe and cigar smokers (among the 30 selected panelists) by employing their average score

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 17. A letter informing the prospective panelists of their results in the primary taste tests during panel selection and training

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

School of Agriculture and Life Sciences

Department of Crop Science
Box 5155 Zip 27607

MEMORANDUM

To: , Prospective Member, NCSU's SMOKERS PANEL

From: FAWKY ABDALLAH

Subject: FIRST SERIES OF TASTE TESTINGS

Date:

Having successfully completed the first series of "Sipping" tests designed to familiarize you with the four basic tastes: sweet, salt, sour, and bitter, and to measure your sensitivities to each of these tastes in terms of Threshold Level, we now bestow upon you membership in our "TASTERS' CLUB"!

Being an itegral part of our program, we feel it is necessary to keep you informed of the progress of the tests. You may be interested in learning your scores in these first tests:

TASTE	THRESHOLD LEVEL	
	DETECTION	RECOGNITION
SWEET	_____	_____
SALT	_____	_____
SOUR	_____	_____
BITTER	_____	_____

(The "Levels" are expressed in the form of arbitrary numbers reflecting increasing concentrations from 1 through 14. If you have any question on how to interpret these scores, please don't hesitate to ask me).

We will proceed next to "Discrimination Tests" (still with solutions) along with the actual "Smoking Tests". I will telephone you and, if it is agreeable with you, we will follow the same time schedule employed in the first series of tests.

We appreciate your spirit of cooperativeness in this undertaking and commend you on your performance.

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Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

Appendix Figure 18. To increase their interest and motivation, panelists were adequately informed of their selection as panel members and of the important role of the panel in the evaluation of smoke flavor

2028559772

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

School of Agriculture and Life Sciences

Department of Crop Science
Box 5155 Zip 27607

March 22, 1973

Memorandum to: Member, N. C. S. U. Smokers Panel

From: Fawky Abdallah R. J. Monroe

J. A. Weybrew

Subject: Results of Screening Tests for Selection of Panel Members

Date:

It is my pleasure to inform you that you have successfully passed the necessary screening tests for selection of panel members. You are among those few people who correctly identified the odd cigarette in 9 or more of the test comparisons. You are now considered a Member of our Panel.

As you are well aware, the objective of this Panel is to ensure that the high quality and flavor excellence of the U. S. flue-cured tobacco is not degraded by changes in cultural practices and curing methods concomitant with total mechanization. Since the ultimate assessment of tobacco flavor can be determined only by smoking cigarettes, we believe that a Smokers Panel is an important and necessary adjunct to any aggressive and progressive tobacco research program.

We will proceed next to smoke evaluation of some test cigarettes "spiked" with different additives. We appreciate your spirit of cooperativeness in this undertaking and commend you on your performance. You may rest assured that as a panel member, your judgement will be highly valued.

2028559773

Source: https://www.industrydocuments.ucsf.edu/docs/tknm0000